INTEGRAL Science Data Centre

OMC Analysis User Manual

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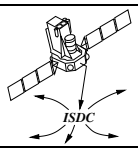 ISDC	OMC Analysis User Manual	
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Contents

Acronyms and Abbreviations . . . vii

Glossary of Terms . . . viii

1 Introduction . . . 1

I Instrument Definition **2**

2 Scientific Performance Summary . . . 3

3 Instrument Description . . . 4

3.1 The Overall Design . . . 4

3.2 The Optics . . . 4

3.3 The CCD Detector . . . 4

4 Instrument Operations . . . 7

4.1 Normal Science Operations Mode . . . 7

4.2 Fast Monitoring Mode . . . 7

4.3 The OMC Input Catalogue . . . 7

4.4 Gamma-Ray Bursts and transient sources . . . 8

5 Performance of the Instrument . . . 9

5.1 Background and Read-out Noise . . . 9

5.2 Limiting Faint Magnitude . . . 9

5.3 Limiting Bright Magnitude . . . 9

5.4 Photometric Accuracy . . . 9

5.5 Focusing . . . 11

II Data Analysis **13**

6 Overview . . . 14

7 Cookbook . . . 16

7.1 Setting Up the Analysis Data . . . 16

7.1.1 Downloading Your Data . . . 17

7.2 Setting the environment . . . 18

7.3 A Walk Through the OMC Analysis . . . 19

7.4 Results . . . 22

8 Basic Data Reduction . . . 27

8.1 *o_cor_science* . . . 27

8.2 *o_gti* . . . 29
8.2.1 *gti_create* . . . 29
8.2.2 *gti_attitude* . . . 29
8.2.3 *gti_import* . . . 30
8.2.4 *gti_merge* . . . 30
8.3 *o_src_analysis* . . . 30
8.3.1 *o_src_get_fluxes* . . . 31
8.3.2 *o_src_compute_mag* . . . 34
8.3.3 *o_ima_build* . . . 36
8.4 *omc_obs_analysis* . . . 38
8.4.1 *o_src_collect* . . . 38
9 Known Limitations . . . 39
A Low Level Processing Data Products . . . 40
A.1 Raw Data . . . 40
A.2 Prepared Data . . . 41
B Instrument Characteristics Data used in Science Analysis . . . 43
C Science Data Products . . . 44
C.1 *o_cor_science* . . . 44
C.2 *o_gti* . . . 44
C.3 *o_src_analysis* . . . 44
C.3.1 *o_ima_build* . . . 45
C.4 *o_src_collect* . . . 46

List of Figures

1 A 3-D cut of the OMC Camera Unit . . . 5
2 Optical system layout. . . . 6
3 Spacecraft & Instrument Coordinate Systems. . . . 6
4 Background evaluation graphics. . . . 10
5 Limiting bright magnitude. . . . 10
6 OMC Point Spread Function. . . . 12
7 Overview of the OMC science analysis. . . . 14
8 GUI for OMC analysis. . . . 23
9 Crab lightcurve. . . . 24
10 Sky map of the ScW 010200210010, 13^{th} shot. . . . 25
11 Image of the Crab box, 13^{th} shot. . . . 26
12 Structure of the *omc_science_analysis* script. . . . 28
13 Illustration of the geometry defining the background and source magnitude calculation. . . . 32

List of Tables

1 OMC parameters and scientific performances . . . 3
2 Photometric accuracy for different background levels (in units of magnitude). . . . 11
3 Parameters for the *omc_science_analysis*. . . . 19
4 The *o_cor_box_fluxes* parameters included in the main script. . . . 28
5 The *gti_create* parameters included in the main script. . . . 29
6 The *gti_attitude* parameters included in the main script. . . . 29
7 The *gti_import* parameters included in the Main script. . . . 30
8 The *gti_merge* parameters included in the Main script. . . . 30
9 The *o_src_get_fluxes* parameters included in the main script. . . . 33
10 Possible values in PROBLEMS column in the *o_src_get_fluxes* output. . . . 34
11 The *o_src_compute_mag* parameters included in the main script. . . . 35
12 The *o_ima_build* parameters. . . . 36
13 The *o_src_collect* parameters. . . . 38
14 Content of **OMC.-SHOT-RAW** Data Structure. . . . 40
15 Content of **OMC.-BOXS-RAW** Data Structure. . . . 40
16 Content of **OMC.-TRIG-RAW** Data Structure. . . . 41
17 Content of **OMC.-SHOT-PRP** Data Structure. . . . 41
18 Content of **OMC.-BOXS-PRP** Data Structure. . . . 41
19 Content of **OMC.-TRIG-PRP** Data Structure. . . . 42
20 Content of **OMC.-DARK-CAL** Data Structure. . . . 43
21 Content of **OMC.-BDPX-CAL** Data Structure. . . . 43
22 Content of **OMC.-PHOT-CAL** Data Structure. . . . 43
23 Content of **OMC.-GOOD-LIM** Data Structure. . . . 43
24 Content of **OMC.-SHOT-COR** Data Structure. . . . 44
25 Content of **OMC.-GNRL-GTI** Data Structure. . . . 44
26 Content of **OMC.-SRCL-RES** Data Structure. . . . 44
27 Content of **OMC.-INTG-RES** Data Structure. . . . 45
28 Content of **OMC.–SKY.-IMA-IDX** Data Structure. . . . 46
29 Content of **OMC.-STAN-RES** Data Structure. . . . 46

Acronyms and Abbreviations

AD	Architectural Design
ADC	Analog to Digital Converter
ADU	Analog-Digital Unit
CCD	Charge-Coupled device
DOL	Data Object Locator
FOV	Field of View
FWHM	Full Width at Half Maximum
GRB	Gamma Ray Burst
GTI	Good Time Interval
IBAS	Integral Burst Alert System
IC	Instrument Characteristics
IJD	Integral Julian Day
ISOC	Integral Science Operations Centre
ISDC	Integral Science Data Center
LED	Light Emitting Diode
TOO	Target of Opportunity
OBT	On-Board Time
OG	Observation Group
OMC	Optical Monitoring Camera
PSF	Point Spread Function
ScW	Science Window
SWG	Science Window Group
TBW	To be written
TM	Telemetry

Glossary of Terms

- *box:* A small CCD window, extracted from the CCD image for transmission to the ground. It is used instead of window or sub-window when needed for clarity.
- *CCD active area:* The CCD area exposed to light
- *CCD storage area:* The CCD active area has a duplicate array of detectors which is masked from light.
- *frame transfer:* A technique to acquire images with a CCD. The charge generated in the active area is transferred quasi-instantaneously to the storage area. This area is the one used for the read-out process, allowing simultaneous read-out of one image while the active area is collecting light for the next one.
- *shot:* Each individual OMC CCD integration for image generation
- *ISDC system:* the complete ground software system devoted to the processing of the *INTEGRAL* data and running at the ISDC. It includes contributions from the ISDC and from the *INTEGRAL* instrument teams.
- *Science Window (ScW):* For the operations, ISDC defines atomic bits of *INTEGRAL* operations as either a pointing or a slew, and calls them ScWs. A set of data produced during a ScW is a basic piece of *INTEGRAL* data in the ISDC system.
- *Observation:* Any group of ScW used in the data analysis. The *observation* defined from ISOC in relation with the proposal is only one example of possible *ISDC observations*. Other combinations of Science Windows, *i.e.,* of observations, are used for example for the Quick-Look Analysis, or for Off-Line Scientific Analysis.
- *Pointing:* Period during which the spacecraft axis pointing direction remains stable. Because of the *INTEGRAL* dithering strategy, the nominal pointing duration is of the order of 20 minutes.
- *Slew:* Period during which the spacecraft is manoeuvred from one stable position to another, i.e., from one pointing to another.

1 Introduction

The 'OMC Analysis User Manual', *i.e.,* this document, was edited to help you with the OMC specific part of the *INTEGRAL* Data Anaysis.

A more general overview on the *INTEGRAL* Data Analysis can be found in the 'Introduction to the *INTEGRAL* Data Analysis' [1]. For the OMC analysis scientific validation report see [3].

The 'OMC Analysis User Manual' is divided into two major parts:

- Description of the Instrument
  This part, based to some extent on the ISOC AO-2 document [2], introduces the *INTEGRAL* on-board Optical Monitoring Camera (OMC).
- Description of the Data Analysis
  This part starts with an overview describing the different steps of the analysis. Then, in the Cookbook Section, several examples of analysis and their results and the description of the parameters are given.

  Finally, the used algorithms are described. A list of the known limitations of the current release is also provided.

In the Appendix of this document you will find the description of the Raw and Prepared Data and also the description of the Scientific Products. If you are interested in Data Structures not described in the Appendix go to the ISDC web-page:

http://isdc.unige.ch/index.cgi?Data+templates

Part I

Instrument Definition

2 Scientific Performance Summary

The Optical Monitoring Camera (OMC) is a wide-field optical instrument using a large-format CCD (charge-coupled device) detector, limited by a relatively low telemetry rate. It measures the optical emission from the prime targets of the high-energy instruments and also from the known optical sources in the field of view. The OMC offers the first opportunity to make observations of long duration in the optical band simultaneously with those at hard X-rays and gamma-rays. Multi-band observations are particularly important in high-energy astrophysics where variability is typically rapid, unpredictable and of large amplitude. Table 1 gives the main OMC parameters.

Table 1: OMC parameters and scientific performances

Parameter	**Baseline value**
Field of view	$4.979° \times 4.979°$
Aperture	5 cm diameter
Focal length	153.7 mm (f/3.1)
Optical throughput	> 70 % at 550 nm
Stray light reduction factor[a] (within UFOV[b])	$\ll 10^{-4}$ (no stray light detected)
Angular resolution	$\approx 23''$ Gaussian PSF (FWHM=1.3 ± 0.1 pix)
Point source location accuracy	$6''$
Angular pixel size	$17.504'' \times 17.504''$
CCD pixels	2061×1056 (1024×1024 image area) ($13 \times 13 \mu m^2$ per pixel)
CCD Quantum efficiency	88% at 550 nm
CCD full well capacity	$\sim 120,000$ electrons/pixel
ADC levels	12 bit signal,4096 levels: ~ 30 cts/digital level (low gain) ~ 5 cts/digital level (high gain)
Frame transfer time	≈ 2 ms
Time resolution	> 3 s
Typical integration times	10 s – 50 s – 100 s
Wavelength range	Johnson V filter (centered at 550 nm)
Limit magnitude (10×200 s, 3σ) (50×200 s, 3σ) (100×200 s, 3σ)	18.1 (m_V) 18.9 (m_V) 19.3 (m_V)
Sensitivity to variations (10×100 s, 3σ)	$\Delta m_V < 0.1$, for $m_V < 16$

[a] This parameter defines the factor by which the flux from any source within UFOV (but outside FOV) is reduced by multiple reflections before reaching the detector surface as background light.

[b] The unobstructed field of view (UFOV) defines the angle which has to be clear to space in order to avoid reflected light directly reaching the optics.

3 Instrument Description

3.1 The Overall Design

The OMC optics are refractive with an entrance aperture of 5 cm diameter and a square field of view of 5°× 5°. A Johnson V filter allows photometric calibration in a standard system. An optical baffle ensures the necessary reduction of scattered sunlight and also the unwanted stray-light coming from non-solar sources outside the FOV. The camera unit is based on a large-format CCD (2061×1056 pixels) working in frame transfer mode (1024×1024 image area and 1024×1024 storage area). This design, with a frame transfer time of around 2 ms, allows continuous measurements and makes it unnecessary to have a mechanical shutter. For pixel to pixel calibration purposes 2 Light Emitting Diodes (LEDs) are installed in the CCD cavity of the camera. These LEDs illuminate the image area of the CCD. The differential response of each pixel to this known illumination pattern is used to build a flatfield correction matrix, required for photometric calibration of the images.

An overall cut-out view of the instrument is given in Figure 1.

3.2 The Optics

The optical system, as shown in Figure 2, consists of :

- a 6-fold lens system composed of two different types of radiation resistant glass.
- a filter assembly; the Johnson V filter has been defined with a combination of 3 mm thick SCHOTT GG495 filter and 2 mm thick SCHOTT BG39 filter;
- a lens barrel giving mechanical support to the lenses and ensuring their alignment.

3.3 The CCD Detector

A CCD consists of several hundred thousand individual picture elements (pixels) on a tiny chip. Each pixel responds to light falling on it by storing a tiny charge of electricity. During the shot, charges are stored in the CCD active area (area exposed to light). After the end of the shot, this area is copied to the storage area, masked from the light. From this storage area, the information is read by the read-out port and transmitted to the Earth. In the OMC case, there are two read-out ports - left one and right one. Only one of them is in the active use, and the second one is planned to be used only in case of problems with the first one. In Figure 3, you will see the OMC coordinates definitions for the left and right read-out ports, and their orientation in comparison with the axes of other instruments.

The Analog to Digital converters (ADCs) that are used for OMC have the capability of digitizing the analog signal coming from the CCD read-out ports to 12 bits, *i.e.,* they provide a discrete output in up to 4096 digital levels. These convertors have been designed to be operated with 2 gain values. At low gain, the full dynamic range of the CCD, 0 – 120 000 cts per pixel (maximum value is defined by the CCD full well capacity), is digitized into 0 – 4095 digital levels (ADU), at a linear scale of ≈30 cts/ADU. At high gain, only the 0 – 20 000 cts per pixel range is digitized into 0 – 4095 ADU, with ≈5 cts/ ADU. This allows a more accurate photometry, down to, approximately, the noise limit of the CCD.

Finally, CCD is cooled by means of a passive radiator (illustrated in Fig. 1) to an operational temperature in the range between −100°C to −70°C.

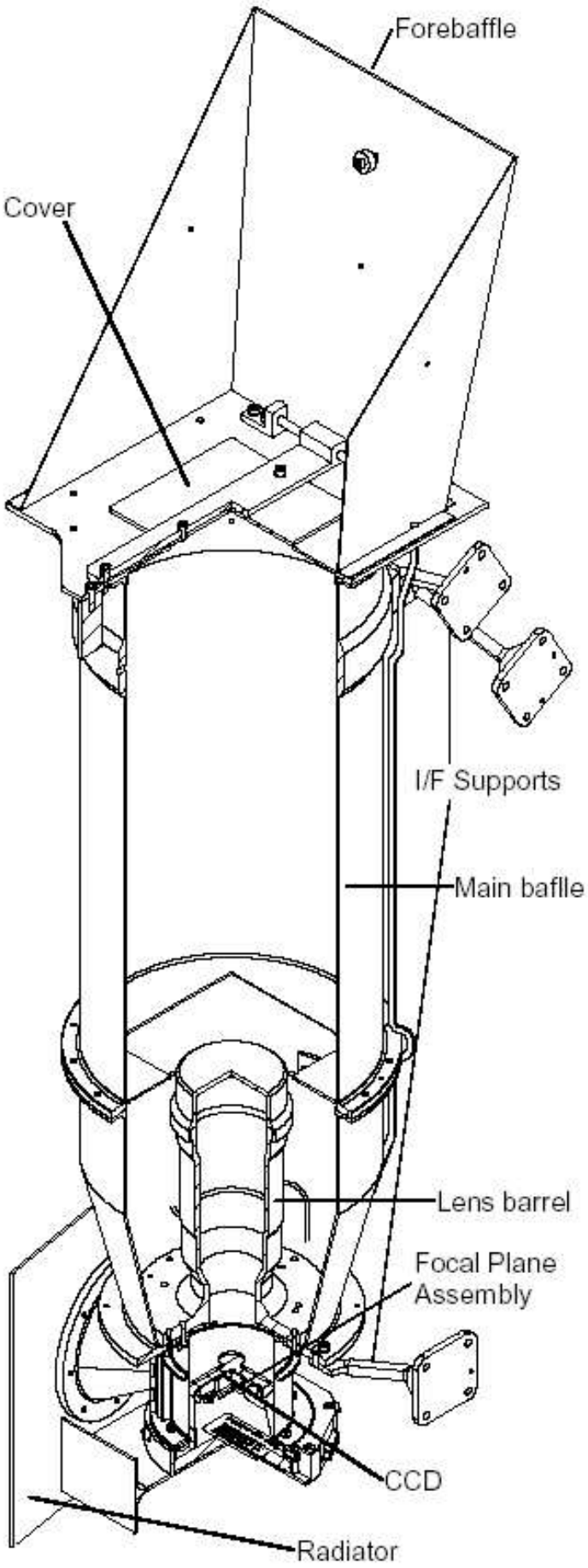

Figure 1: A 3-D cut of the OMC Camera Unit

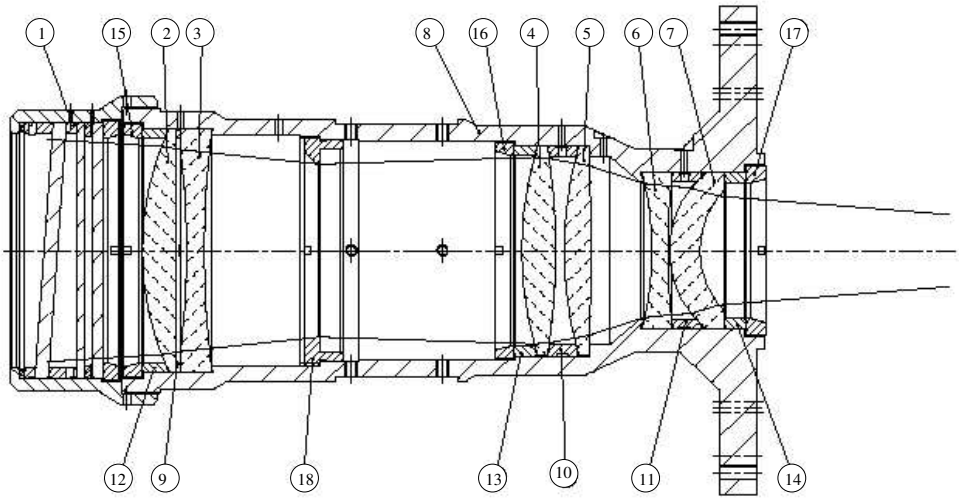

Figure 2: Optical system layout. 1: filter assembly housing; 2-7: lenses; 8: lens barrel; 9-14: spacers; 15-17: retainers; 18: aperture stop

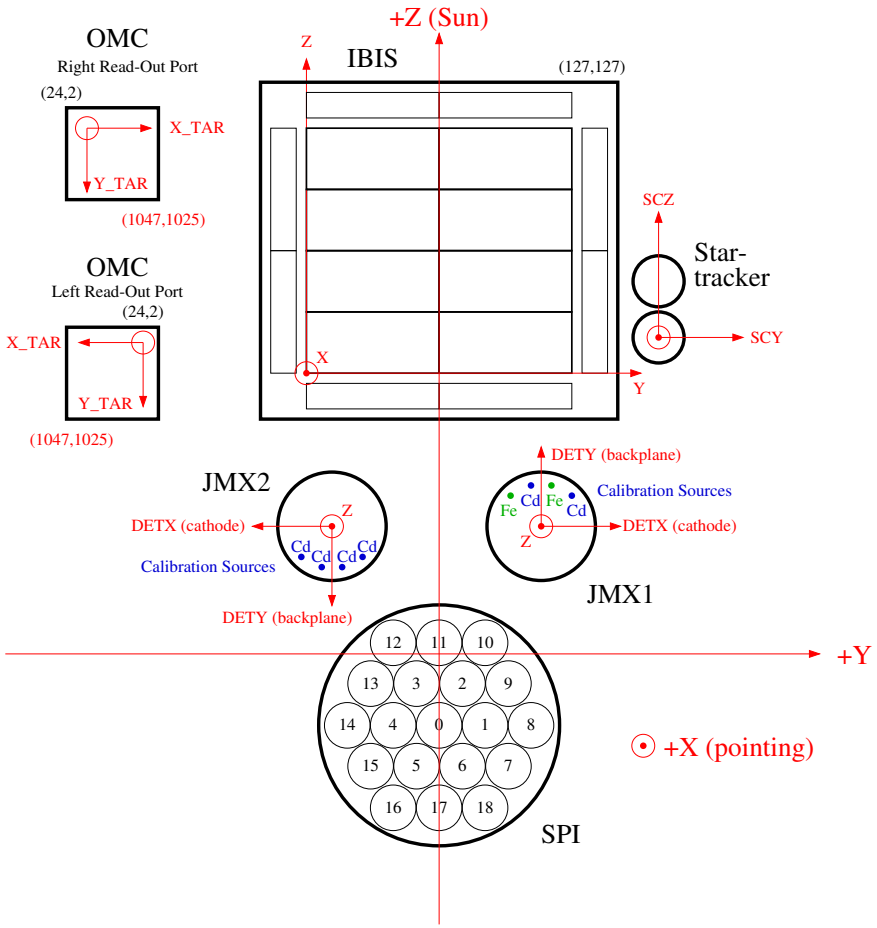

Figure 3: Spacecraft & Instrument Coordinate Systems. Note that the X-axis of the spacecraft is defined by the pointing direction.

4 Instrument Operations

Because of telemetry constraints (only ≈2.2 kbps are allocated to OMC), it is not possible to transmit the entire OMC image to the ground. For this reason, windows are selected around the proposed gamma-ray target as well as other targets of interest in the same field of view. The observers obtain the data pertinent to their target, as well as all the other OMC CCD sub-windows taken during the observation. These additional targets are automatically selected from the OMC Input Catalogue. Two observation modes are available to the observer: the normal and the fast monitoring modes.

4.1 Normal Science Operations Mode

In the normal science operations mode, OMC monitors the optical flux of a number of targets, including the high-energy sources within its FOV, other sources of interest, stars for photometric calibration and masked pixels from the CCD to monitor the dark current. Variable integration times during a pointing allow monitoring of both bright and faint sources. Operations are performed automatically in the following way:

- The sequence starts by obtaining a series of images of ≈10 "astrometric" reference stars, spread over the field of view. This makes it possible to measure the pointing of the OMC optical axis with an accuracy of around 0.3 pixels (≈ 6″).
- Then a set of photometric stars is observed (≈ 10 stars in the field of view with good photometric quality).
- The CCD, centered in a target field, is then exposed with the following sequence of integration times: 10 s - 50 s - 200 s. After each exposure the full frame is transferred to the occulted part of the chip and the next integration starts. An optimum use of the CCD, from the point of view of the noise (read-out and cosmic rays), is obtained for integration times of around 200 s, so that for the faintest objects several exposures of 200 s are summed up during the analysis on the ground. The number of integrations that can be added depends on the time during which the spacecraft keeps the same pointing without dithering (typically 30 min.). The brightest stars saturate their corresponding pixels for such integration times, but a combination of short and long exposures is performed so as to increase the magnitude range for a given field.
- A number of windows (of typically 11×11 pixels, or ≈ $3' \times 3'$) are extracted around each object of interest and transmitted to the ground.

4.2 Fast Monitoring Mode

In the normal mode it is not possible to perform a continuous monitoring with a time resolution finer than 10 seconds. Therefore, when fast variability is expected, the fast monitoring mode can be chosen. With this mode, integrations of 3 seconds are performed at intervals of 4.5 seconds and only the sections of the CCD containing the target of interest are read from the CCD and transmitted. This, of course, implies that the position of the source is known with an accuracy better than the window size (11×11 pixels, *i.e.,* $3' \times 3'$), and that the source is bright enough to be monitored with integration times below 10 s (see Fig. 5 below).

4.3 The OMC Input Catalogue

As explained above, besides the proposed targets, OMC observes astrometric and photometric stars and other targets of scientific interest within its field of view at a given time. For this purpose, a catalogue ([5]) has been compiled by the OMC team containing over 500,000 sources, including:

- Known optical counterparts of gamma-ray sources.

- Most known optical counterparts of X-ray sources.
- X-ray sources detected and catalogued by ROSAT.
- Quasars observable with OMC.
- Additional known AGNs.
- Known eruptive variable stars (including novae and cataclysmic).
- Variable objects which may require an additional optical monitoring.
- HIPPARCOS reference stars for positioning and photometric calibration

During the mission, additional sources of interest will be added to the catalogue, namely:

- Newly-discovered optical counterparts of high-energy sources, especially sources discovered during the Galactic Plane Survey
- Regions of special interest for *INTEGRAL* science.
- New supernovae.
- New eruptive variable stars.
- Any other Target of Opportunity (TOO)

For each scheduled observation, the coordinates of all the targets of interest within the corresponding field of view are extracted from the OMC input catalogue.

4.4 Gamma-Ray Bursts and transient sources

The *INTEGRAL* Burst Alert System (IBAS) is searching for gamma-ray bursts (GRB) using IBIS/ ISGRI events. If IBAS detects a GRB within the OMC FOV, a near-real-time command will be sent to OMC. Upon reception of this telecommand, OMC stops the observations planned for this pointing and starts to monitor a single window of 91×91 pixels ($\approx 24' \times 24'$) around the region where the burst has been detected, with a fixed integration time of 100 s. This "trigger" mode will be active during the rest of the pointing as well as during subsequent pointings as long as the bursting source is in the OMC FOV. The expected delay between the start of the burst and the start of OMC monitoring is less than 1 minute. Specifically, the OMC monitoring starts less than 15 seconds after the IBAS trigger. This makes it possible to obtain slightly delayed but simultaneous optical, X-ray, and gamma-ray data of any burst taking place within the OMC FOV.

5 Performance of the Instrument

5.1 Background and Read-out Noise

There are two main sources of background flux for OMC, both related to the rather large angular pixel size of $17.504'' \times 17.504''$: scattered sunlight (zodiacal light) and unresolved stellar sources. Maximum background conditions correspond to pointings towards the galactic plane with maximum zodiacal light, while the minimum background is achieved around the galactic pole with minimum zodiacal light. The left side of Figure 4 shows the average number of stars brighter than a given magnitude expected to be contained within a single OMC pixel. It can be seen that, on average, no source confusion is expected for objects brighter than m_V=17 at any galactic latitude. For m_V=18.0, source confusion becomes problematic in regions very close to the galactic plane. It is important to stress that on the galactic plane we expect to have on average more than one star per pixel with m_V between 17 and 19. The density of stars on the galactic plane indeed determines the limiting magnitude of the instrument. At galactic latitudes $|b|$ >30°, the problem of source confusion becomes negligible, except for specific cases in which bright stars are separated by just a few arcseconds.

5.2 Limiting Faint Magnitude

Assuming a minimum level of background and the combination of 10 exposures of 200 s each, the limiting magnitude of OMC is found to be $m_V = 18.1$ (3 σ detection level). This value corresponds to a limiting sensitivity of the instrument of 2.1×10^{-16} erg cm^{-2}s^{-1}Å^{-1} or, alternately, 5.8×10^{-5} ph cm^{-2}s^{-1}Å^{-1}, at 550 nm. At a maximum background level, the limiting magnitude is $m_V = 17.5$. Note that these sensitivities can only be achieved for isolated stars for which the background can be properly estimated. Figure 4 shows the limiting magnitude for both maximum and minimum background as a function of integration time, assuming in all cases that 10 images have been combined to increase the signal-to-noise ratio.

5.3 Limiting Bright Magnitude

The full well capacity of the CCD constrains the magnitude of the brightest stars that can be measured without pixel saturation for a given integration time. With 10 s integrations, the central pixel becomes saturated for objects brighter than m_V=7. With integrations of 200 s, even stars with $m_V \approx 10$ start to saturate the CCD. Severe saturation of the CCD might imply losing information from the surrounding pixels and potentially from the column containing the source, but no damage is expected on the detector. The left side of Figure 5 shows the expected number of counts on the CCD as a function of V magnitude for a 10 s integration. This number corresponds to the counts expected in the central (brightest) pixel only. Finally, the right side of Figure 5 gives the integration time at which stars of different magnitudes start to saturate the CCD.

5.4 Photometric Accuracy

Table 2 shows the expected error (expressed in magnitudes) of a given measurement for the quoted integration time and magnitude. "Effective" integration time means the total exposure after combining several shots. The value of 300 s corresponds to the "typical effective exposure" obtained by OMC Standard Analysis using default parameters. A value of 900 s corresponds to the maximum effective exposure one can get in the OMC standard analysis (when changing the default parameters). An effective exposure of 900 s is also a representative value for an entire 5×5 dither pattern ($\sim$ 2000 s pointing). Of course, these values should be used as a guide: they are the best values which can be obtained with the latest version of analysis software and are only valid for isolated stars in the "staring" mode.

The values for photometric accuracy have been computed by taking into account the most current knowledge of the OMC instrument. One can see in Table 2 that good photometry can be performed in the V band for objects of quite different brightness. Note that these accuracies can only be obtained for isolated stars

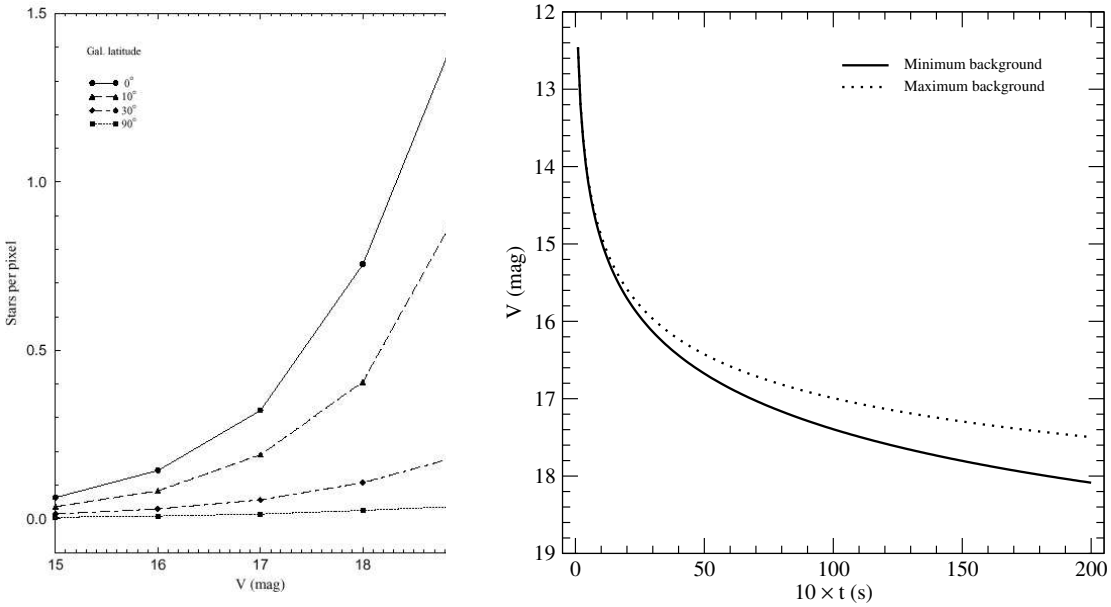

Figure 4: **Left:** Average number of stars per pixel brighter than a given V magnitude at different galactic latitudes. **Right:** Limit magnitude (detection at 3σ significance) in V in best (galactic pole, no zodiacal light) and worst (galactic plane with zodiacal light) conditions as a function of integration time, assuming stacking of only 10 individual images.

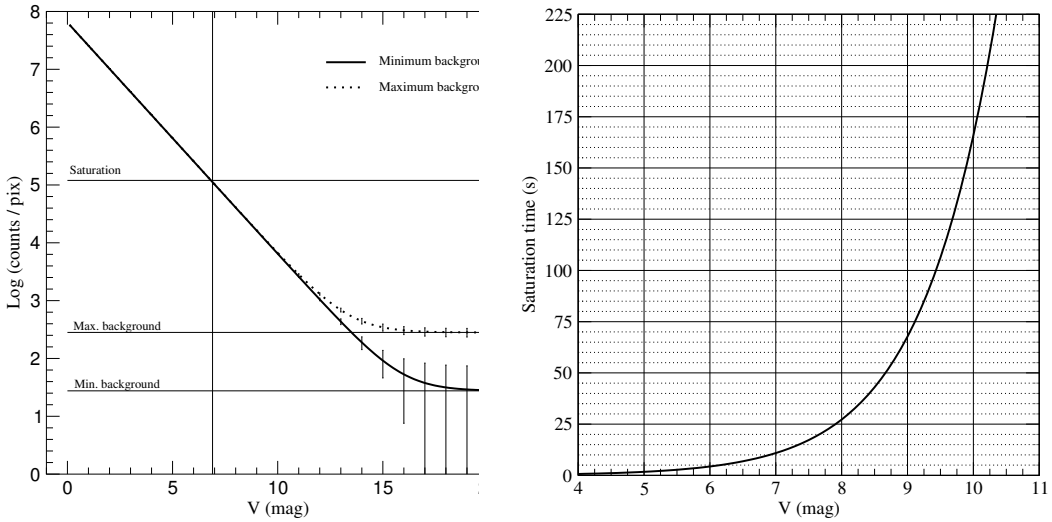

Figure 5: **Left:** Number of counts on the central (brightest) pixel as a function of stellar magnitude. The levels corresponding to minimum and maximum backgrounds have been indicated, as well as the countrate at which the CCD pixels saturate. The curve has been computed assuming 10 s of integration time, but the Y scale can be easily converted to any other integration values.
Right: Integration time at which a star of given V magnitude saturates the central pixel.

for which the background can be properly estimated. Furthermore, in case of dithering, the photometric disperion σ is > 0.015 mag in all cases. This value (0.015) is the accuracy of the OMC flatfield matrix. So, if the source is observed in different detector pixels, as occurs for a dithered observation, the accuracy of the flatfield produces an additional scattering of observed magnitudes corresponding to 0.015 mag.

Table 2: Photometric accuracy for different background levels (in units of magnitude).

source $m_V \rightarrow$	8	10	12	14	16
effective[a] exposures $\downarrow$	assuming typical background level:				
10 s	0.007	0.02	0.1	-	-
300 s	-	0.005	0.01	0.045	0.3
900 s	-	0.003	0.006	0.026	0.17

5.5 Focusing

The focusing capabilities of the OMC system depend very slightly on the lense temperature and the pixel location over the detector. The PSF (Point Spread Function) follows a Gaussian distribution whose FWHM (Full Width at Half Maximum) remains in the range 1.2 ot 1.4 pixels in most cases, as shown in Figure 6.

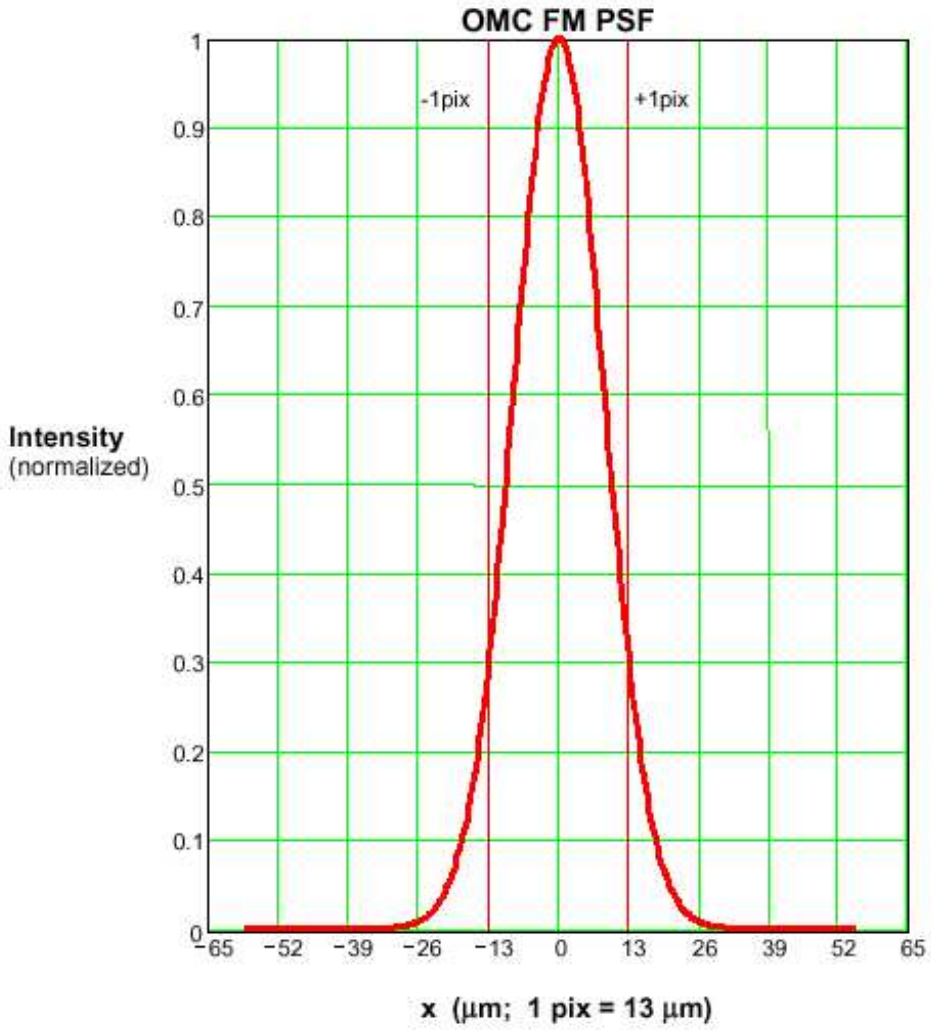

Figure 6: OMC Point Spread Function. The plot shows a fit to the average PSF measured under different conditions. The FWHM remains in all cases below ≈ 1.3 pixels. More than 90% of the energy falls within a region of 3×3 pixels.

Part II

Data Analysis

6 Overview

As it was said in the previous part (see Sections 4.1, 4.2), during science mode the OMC takes images of the full field of view every 1 to 255 seconds depending on the integration time for the different targets. Each individual OMC CCD integration for image generation is called a "shot". The full image (or a section) is transferred to the data processing electronics. Due to TM constraints, only a number of sub-windows, typically of 11×11 pixels, are extracted around the positions of objects of interest. About 100 such windows are extracted for exposures of 100 s. In the following, the term "box" is used for such a sub-window for clarity.

In the Data Preparation step of the automatic processing at ISDC, the OMC raw data are compared with the available planning data. In addition, the measured fluxes of individual pixels and the fluxes averaged over boxes are compared with given limits. Shots and boxes that deviate from the planning data are flagged accordingly. Boxes are also flagged for unusually low fluxes or signs of saturation. All this information is used by the scientific analysis software to exclude whole shots or individual boxes which have been flagged as bad during Data Preparation or which fall outside user limits for their properties.

As it was explained in the Introduction to the *INTEGRAL* Data Analysis [1], the scientific analysis of all the *INTEGRAL* instruments is split into a number of steps with similar tasks. The scientific analysis of the OMC data is the least complex of all the *INTEGRAL* instruments. The main script *omc_science_analysis* includes four main steps (see Figure 7).

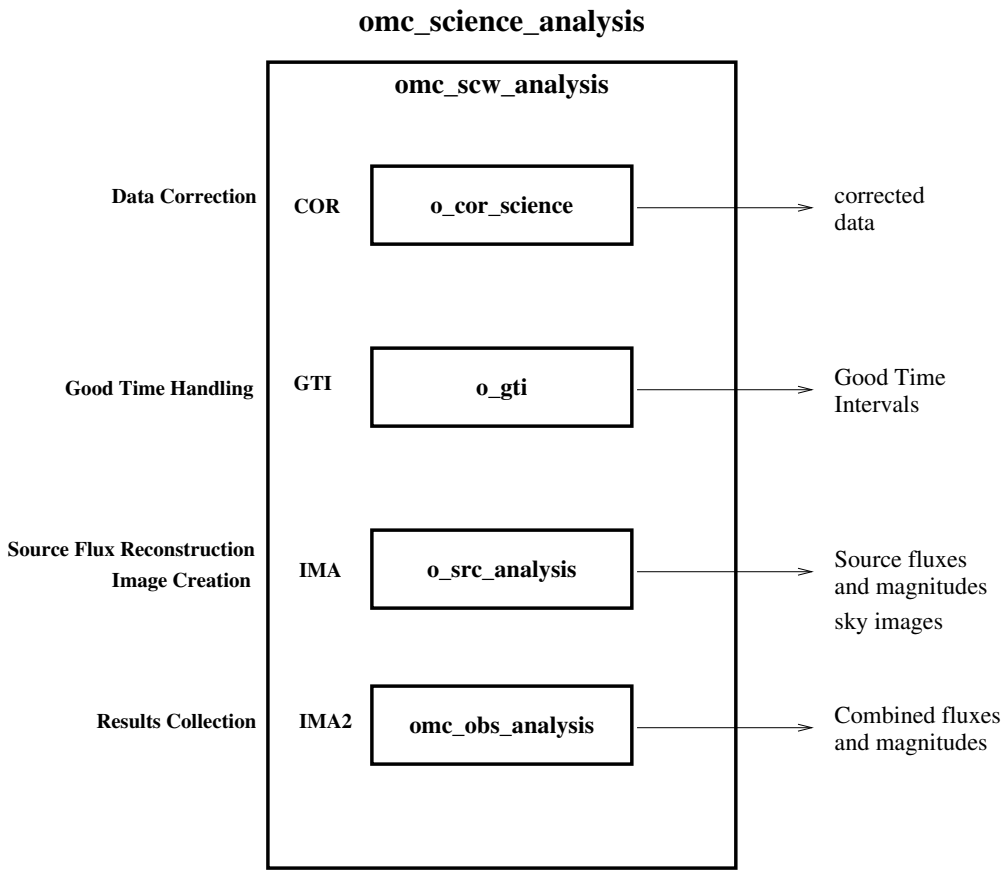

Figure 7: Overview of the OMC science analysis.

COR – Data Correction

At this step, the appropriate calibration data (dark current, bias, flatfield) for the current science window group are selected and the corrected pixel values for the subsequent analysis are calculated.

GTI – Good Time Handling

At this step, Good Time Intervals (GTI) for the current Science Window are derived, based on housekeeping data and attitude stability information.

IMA – Source Flux Reconstruction and Trigger Image Creation

At this step, the fluxes as well as normal and fast mode images of the individual sources are calculated and the source magnitudes are derived. With default parameter settings the images are created only if during the observation an IBAS trigger occurs. In this case a small image, typically 81×81, or 91×91 pixels around the IBAS position for a possible burster is created.

IMA2 – Results Collection

As explained in [1], within the ISDC Data Model, the data concerning one observation are distributed between different files. All the data from one pointing (a period during which the spacecraft axis pointing direction remains stable) or slew (a period during which the spacecraft manoeuvres from one stable position to another) are grouped to so called Science Windows Groups. The observation usually contains more than one Science Window, and all the data related with the observation are grouped to an Observation Group. At the IMA2 level, the results distributed over several Science Windows are collected into a single table.

7 Cookbook

This chapter describes how to use the OSA OMC software on the extended Crab source. It covers the following steps:

- Setting up the analysis data
- Setting the environment
- Launching the analysis
- Interpreting the results

We assume that you have already successfully installed the ISDC Off-line Scientific Analysis (OSA) Software version 5.0 (The directory in which OSA is installed is referred later as the ISDC_ENV directory). If it is not the case, look at the "Installation Guide for the *INTEGRAL* Off-line Scientific Analysis" [4] for detailed help.

7.1 Setting Up the Analysis Data

In order to set up a proper environment, you first have to create an analysis directory (e.g `omc_data_rep`) and "cd" into it:

```
mkdir omc_data_rep
cd omc_data_rep
setenv REP_BASE_PROD  $PWD
```

This working directory will be referred to as the "REP_BASE_PROD" directory in the following. All the data required in your analysis should then be available from this "top" directory, and they should be organized as follow

- **scw/** : data produced by the instruments (e.g., event tables) cut and stored by ScWs
- **aux/** : auxiliary data provided by the ground segment (e.g., time correlations)
- **cat/** : ISDC reference catalogue
- **ic/** : Instrument Characteristics (IC), such as calibration data and instrument responses
- **idx/** : set of indices used by the software to select approriate IC data

The OMC example presented below is based on observations of the Crab from Revolution 102.

Part of the required data may already be available on your system[1]. In that case, you can either copy these data to the relevant working directory, or better, create soft links as follow

```
ln -s directory_of_ic_files_installation__/ic ic
ln -s directory_of_ic_files_installation__/idx idx
ln -s directory_of_cat_installation__/cat cat
ln -s directory_of_local_archive__/scw scw
ln -s directory_of_local_archive__/aux aux
```

[1] The Instrument Characteristics files (OSA_IC package) and the Reference Catalogue (OSA_CAT package) are part of the OSA software distribution. They should be installed following the "Installation Guide for the *INTEGRAL* Data Analysis System" [4].

Then, just create a file 'omc.lst' containing the 2 lines:

```
scw/0102/010200210010.001/swg.fits[1]
scw/0102/010200220010.001/swg.fits[1]
```

which is the list of Scws you want to analyze (technically, we call them DOLs -Data Object Locators-, i.e. a specified extension in a given FITS file). [2].

This file name 'omc.lst' will be used later as an argument for the og_create program (see Section 7.3).

Alternatively, if you do not have any of the above data on your local system, or if you do not have a local archive with the scw/ and the aux/ branch available, follow the next section instructions to download data from the ISDC WWW site.

7.1.1 Downloading Your Data

To retrieve the required analysis data from the archive, go to the following URL:
http://isdc.unige.ch/index.cgi?Data+browse

You will reach the W3Browse web page which will allow you to build a list of Science Windows (Scws) needed to create your observation group for OSA.

- Type the name of the object (Crab) in the 'Object Name Or Coordinates:' field
- Click on the 'More Options' button at the top or at the bottom of the web page

- Deselect the 'All' checkbox at the top of the Catalog table, and select the 'SCW - Science Window Data' one
- Press the 'Specify Additional Parameters' button at the bottom of the web page
- Deselect the 'View All' checkbox (press twice on it) at the top of the Query table
- Select 'scw_id' and put the value '0102*' (without the quotes) to specify all Scws from Revolution 102
- Select 'scw_type' and put the value 'pointing' (without the quotes), or simply 'po*' to get only pointings
- Press the 'Start Search' button at the bottom of the web page

At this point, you should be at the Query Results page with all the Scws available for revolution 102.
- Sort the 'Scw_id' column by clicking on the left arrow below the column Name

You can then select the two Scws we are interested in, i.e 010200210010 and 01020022010.

Press the '**Save SCW list** for the creation of Observation Groups' button at the bottom of that table and save the file with the name 'omc.lst'. The file name 'omc.lst' will be used later as an argument for the og_create program (see Section 7.3). In this file, you should find the 2 lines:

```
scw/0102/010200210010.001/swg.fits[1]
scw/0102/010200220010.001/swg.fits[1]
```

You should then download the data pressing the '**Request** data products for selected rows' button. In the 'Public Data Distribution Form', provide your e-mail address and press the 'Submit Request' button. You will be e-mailed the required script to get your data and the instructions for the settings of the IC files and the reference catalogue. Just follow these instructions.

[2] When an analysis script asks you to specify the DOL, you should specify the path of the corresponding FITS file, and the corresponding name or number of the data structure in square brackets(do not forget that numbering starts with 0!). See more details in the Introduction to the INTEGRAL Data Analysis [1]. Please note that the naming scheme is different for revision 1 and revision 2 data. For the revision 1 data, the name of the prepared Science Window Group is `swg_prp.fits` instead of `swg.fits`

7.2 Setting the environment

Before you run any OSA software, you must also set your environment correctly.

The commands below apply to the `csh` family of shells (i.e `csh` and `tcsh`) and should be adapted for other families of shells[3].

In all cases, you have to set the `REP_BASE_PROD` variable to the location where you perform your analysis (e.g the directory `omc_data_rep`). Thus, type:

```
setenv REP_BASE_PROD  $PWD
```

Then, if not already set by default by your system administrator, you should set some environment variables and type:

```
setenv ISDC_ENV directory_of_OSA_sw_installation
setenv ISDC_REF_CAT $REP_BASE_PROD/cat/hec/gnrl_refr_cat_0020.fits\[1]
source $ISDC_ENV/bin/isdc_init_env.csh
```

The idea is to:

- set `ISDC_ENV` to the location where OSA is installed
- set `ISDC_REF_CAT` to the DOL of the ISDC Reference Catalog
- run the OSA set-up script (`isdc_init_env.csh`) which initializes further environment variables relative to `ISDC_ENV`.

Besides these mandatory settings, there are two optional environment variables (COMMONLOGFILE and COMMONSCRIPT) which are useful.

- By default, the software logs messages to the screen (STDOUT). To have also these messages in a file (i.e common_log.txt) and make the output chattier[4], use the command:

  ```
  setenv   COMMONLOGFILE +common_log.txt
  ```

- As your level of expertise with the software increases, you may wish to not have the GUIs pop up when you launch your analysis. In this case, the variable COMMONSCRIPT must be defined:

  ```
  setenv COMMONSCRIPT 1
  ```

  To revert to having the GUI, unset the variable:

  ```
  unsetenv COMMONSCRIPT
  ```

[3] If the setenv command fails with a message like:'setenv: command not found' or 'setenv: not found', then you are probably using the sh family. In that case, please replace the command 'setenv my_variable my_value' by the following command sequence 'my_variable=my_value ; export my_variable'
In the same manner, replace the command 'source my_script' by the following command '. my_script' (the '.' is not a typo!).

[4] For example, the exit status of the program will now appear.

7.3 A Walk Through the OMC Analysis

After setting up the data and the environment, you are ready to call the analysis script on the Crab region observations defined above and stored in the omc.lst file.

Firstly, create an Observation Group (see the description of the executable *og_create* in the Toolbox section of the Introduction to the *INTEGRAL* Data Analysis [1]):

```
og_create idxSwg=omc.lst ogid=crab  baseDir="./" instrument=OMC
```

As a result, the directory `$REP_BASE_PROD/obs/crab` will be created. It contains the files `og_omc.fits` and `swg_idx_omc.fits` as well as the subdirectory `scw` necessary for the analysis.

You are now ready to start the analysis.

```
cd obs/crab
omc_science_analysis  ogDOL="og_omc.fits[1]" \
                      startLevel="COR" endLevel="IMA2" \
                      IMA_timestep=600  IMA_magboxsize=5
```

This command launches the analysis of the data attached to the Observation Group (`ogDOL="og_omc.fits[1]"`). The analysis will pass all levels from Data Correction (`startLevel="COR"`) until Flux Reconstruction and Results Collection (`endLevel="IMA2"`). In order to obtain significant results for weak sources, we want to combine the data so that the exposure of the new set is close to the `IMA_timestep` value of 600 s. The last parameter, `IMA_magboxsize=5` chooses the 5×5 pixel area from which the flux will be collected for determination of the magnitude.

Crab is an extended source for OMC. This is why to determine the V magnitude (integrated over the source), we choose to collect the flux from the 5×5 box centered on the brightest pixel, which is slightly larger than for a point source.

After this command, the script launches the Graphical User Interface (GUI)(see Fig. 8) and you have a chance to check the parameter settings.

In Table 3, we list all the parameters of the main script with a brief explanation. The main panel of the GUI shows only the most important parameters of the script. These parameters are marked in bold in the Table. To access the other parameters, click on the "`hidden`" button in the GUI main panel.

Once you are satisfied with your settings, save them by pressing the "`Save`" button and then press "`Run`" to start the data reduction.

The detailed description of the main script structure and algorithms is given in Section 8.

Table 3: Parameters for the *omc_science_analysis*.

Name	Type	Description
omc_science_analysis		
ogDOL	string	DOL of Observation Group to be analyzed default: "`./og_omc.fits[GROUPING]`"
startLevel	string	Analysis level at which analysis begins possible values: "`COR`" - "`IMA2`" default: "`COR`"
endLevel	string	Analysis level at which analysis finishes possible values: "`COR`" - "`IMA2`" default: "`IMA`"

chatter	integer	Verbosity level of the outputs possible values: `0` – `3`, with `1` as normal default: `1`
IC_Group	string	DOL of the Instrument Characteristics master group. This group is accessed by the script to find the calibration data relevant for the current Science Window. default: "`../../idx/ic/ic_master_file.fits[1]`"
IC_Alias	string	Selection alias for Instrument Characteristics. By changing this alias different instances of IC data can be selected. default: "`OSA`"
Parameters specific to COR level		
COR_flatField	string	DOL of flatfield image (" " =take from IC) default: " "
COR_darkCurrent	string	DOL of dark current & bias calibration table (" " =take from IC) default: " "
COR_biastime	integer	Integration time in sec for bias derivation possible values: `0` – `100000` default: `630`
COR_kscKappa	integer	Number of Standard Deviations for KSC algorithm possible values: `1` – `10` default: `3`
COR_higain	real	Multiplication factor for conversion to electrons for high gain default: `5.0`
COR_lowgain	real	Multiplication factor for conversion to electrons for low gain default: `30.0`
Parameters specific to GTI level		
GTI_gtiOmcNames	string	Names of OMC GTIs to be merged empty=use default default: " "
GTI_gtiScNames	string	Names of spacecraft GTIs to be merged empty=use default default: " "
GTI_omclimitTable	string	DOL of table with the OMC parameter limits " " =take from IC file. default: " "
GTI_sclimitTable	string	DOL of table with spacecraft parameter limits " " =take from IC file. default: " "
GTI_attTolerance	real	Accepted attitude variability [arc min] possible values: `0.` – `180.` default: `0.5`
GTI_BTI_Dol	string	DOL of a bad time interval table (GNRL-INTL-BTI) default: " "
GTI_BTI_Names	string	Input BTI names to be considered default: " "
GTI_gtiUser	string	DOL of the user GTI table " "= there is none. default: " "
GTI_TimeFormat	string	Time format in which the user GTI is given. possible values: "`IJD`", "`UTC`", "`OBT`" default: "`IJD`"
GTI_Accuracy	string	Used accuracy for OBT to IJD conversion and vice versa. possible values: "`any`", "`inaccurate`", "`accurate` default: "`any`"
Parameters specific to IMA level		

IMA_timestep	integer	Approximate integration time of output exposures [s].The actual integration time depends on the times of individual shots and the available time per Science Window. Exposure times within a Science Window are roughly balanced, modifying the given value as required. possible values: `0.` – `100000.` default: `630`
IMA_minshottime	integer	Minimum allowed shot integration time. Shots with shorter integration times will be skipped. default: `0`
IMA_maxshottime	integer	Maximum allowed shot integration time. Shots with longer integration times will be skipped. default: `300`
IMA_maxCentOff	integer	Maximum shift for re-centering integration box. If this is larger than zero, a search for the brightest pixel within this range around the box center is done and the integration box is centered on that pixel. This allows to cope with the fact that even under optimal circumstances not all sources are perfectly centered in their subwindows. possible values: `0`, `1`, `2` default: `2`
IMA_numSigma	integer	Minimum standard deviations for peak search in re-centering possible values: `0` – `10000` default: `2`
IMA_magboxsize	integer	Integration box size for deriving magnitudes possible values: `1` = central pixel, `3` = 3×3 area, `5` = 5×5 area default: `5`
IMA_skyStdDev	real	Maximum acceptable Standard Deviation on sky background default: `10.0`
IMA_triggerImage	boolean	Make image if trigger data found in SWG default: `yes`
IMA_scienceImage	boolean	Make image of science data found in SWG default: `no`
IMA_minSNR	real	minimum acceptable signal to noise ratio default: `1.0`
IMA_noiseLowLeft	real	Read-out noise in e^- for low GAIN, left read-out port possible values: `0.` – `10000.` default: `45.`
IMA_noiseLowRight	real	Read-out noise in e^- for low GAIN, right read-out port possible values: `0.` – `10000.` default: `49`
IMA_noiseHighLeft	real	Read-out noise in e^- for high GAIN, left read-out port possible values: `0.` – `10000.` default: `33.`
IMA_noiseHighRight	real	Read-out noise in e^- for high GAIN, right read-out port possible values: `0.` – `10000.` default: `35.`
IMA_minBoxFrac	real	Minimum fraction of planned boxes actually observed possible values: `0.` – `1.` default: `0.9`
IMA_minTimeFrac	real	Minimum fraction of planned time actually observed possible values: `0.` – `1.` default: `0.99`
IMA_usePrp	boolean	Use prepared data for quality checking default: "`yes`"

IMA_badPixels	string	DOL of Bad Pixel Table (“ ”=take from IC) default: “ ”
IMA_photCal	string	DOL of photometric calibration curve (“ ”=take from IC) default: “ ”

7.4 Results

The files containing results of the OMC analysis are written into the directory `$REP_BASE_PROD/scw` separately for each Science Window (RRRRPPPPSSSF is the number of the Science Window):

```
scw/RRRRPPPPSSSF/omc_intg_res.fits
scw/RRRRPPPPSSSF/omc_srcl_res.fits
```

The first file (`omc_intg_res.fits`) contains the description of the integration periods chosen by the program. The column TELAPSE gives you the elapsed time covered by the integration. The time of the integrations depends on the type of the shots (given in the column SHOTTYPE) – it is close to the value defined by the parameter IMA_timestep (600 seconds in a given example) for the science shots (SHOTTYPE = 2) and much smaller for the photometry shots (SHOTTYPE = 1), see Section 8.3 for more details.

The second file (`omc_srcl_res.fits`) contains a table with information on the source fluxes (each row corresponds to one target box).

Detailed information on the content of the output files is given in the appendix (Section C).

Combined results are written to the file:

```
omc_stan_res.fits
```

This file is a big table with the results obtained for all shots and boxes (see Table 29 in the appendix for the description). To select the results corresponding to the source of interest, the easiest way is to use the program *fcopy* from the FTOOLS package and source `OMC_ID` as a selection string. For this you should find your source in the OMC reference catalog. You can use the browse interface at *http://sdc.laeff.esa.es/omc/* ([5]). It is possible to query using the SIMBAD source name or search around the source position. Now one can select all the rows with the given `OMC_ID` into a file `crab_id_res.fits`:

```
fcopy "omc_stan_res.fits[1][OMC_ID == '1309000071']" crab_id_res.fits
```

Otherwise, one can select all the rows having `RA_OBJ` and `DEC_OBJ` columns values **exactly** equal to the Crab coordinates (as they are given in the OMC catalog):
RA_OBJ==8.363291667000E+01 and DEC_OBJ==2.201444444000E+01 respectively:

```
fcopy "omc_stan_res.fits[1][RA_OBJ==8.363291667000E+01&&DEC_OBJ==2.201444444000E+01]" \
crab_coord_res.fits
```

This should give the same result as selecting the rows with the given OMC_ID.

Now you can plot the OMC lightcurve of the Crab with e.g. the plot tool of **fv** by selecting to plot the dependence of MAG_V on BARYTIME (the result should resemble Figure 9). Note that BARYTIME (the barycentric time of the first element of a given data set) is in IJD, and the length of the data set TELAPSE is in seconds, so the conversion to the single format is necessary. The meaning of all the columns is given in Table 29, Section C.4. Due to the non-uniformity of the Crab background in the frame surrounding the 5×5 area (see Figure 13), the computed error bars are rather large.

If the IBAS trigger occurs during the observation, the small image, typically 81×81, or 91×91 pixels around the IBAS position for a possible burster is downloaded. The resulting image is created at the IMA level.

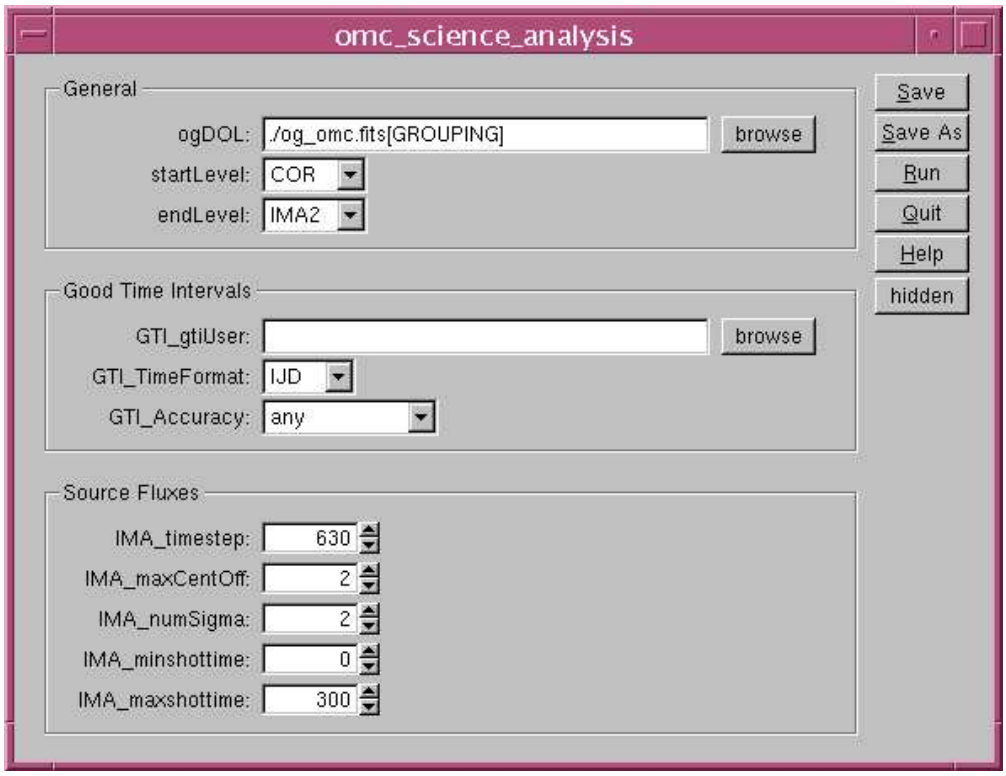

Figure 8: GUI for OMC analysis.

This process is controlled with the parameter `IMA_triggerImage`, which is set to `yes` by default. If another parameter `IMA_scienceImage` is set to yes, a file with one image per shot in the Science Window will be created. This file can be large (a few Megabytes per shot and we have a few dozen of shots typically), so the default value of this parameter is `no`.

However, with the *o_ima_build* program you can select shots for which you would like to build an image with the boxes located in their real position on the OMC CCD. For example, let us first create, using the corrected data (`datalevel=''COR''`), a fits file `FullField.fits` which will contain 7 images of the full OMC field of view for shots `11` to `17` in Science Window `010200210010`:

```
o_ima_build inswg="scw/010200210010.000/swg_omc.fits[1]"\
 outfitsname="FullField.fits" datalevel="COR" \
 startshot=11 endshot=17
```

The resulting images resemble that of Fig. 10. If one is interested in the image of the small box around the Crab, one can give an additional parameter `omc_id=''1309000071''` to the *o_ima_build* tool. As a result, one should obtain an image like that of Fig. 11. As already pointed out, one can now check from the image of the box that the Crab is an extended source for OMC.

All parameters of *o_ima_build* are also available in the main script (*omc_science_analysis*). So, you could also obtain the same image by setting the corresponding parameters in the script, instead of running by hand *o_ima_build*.

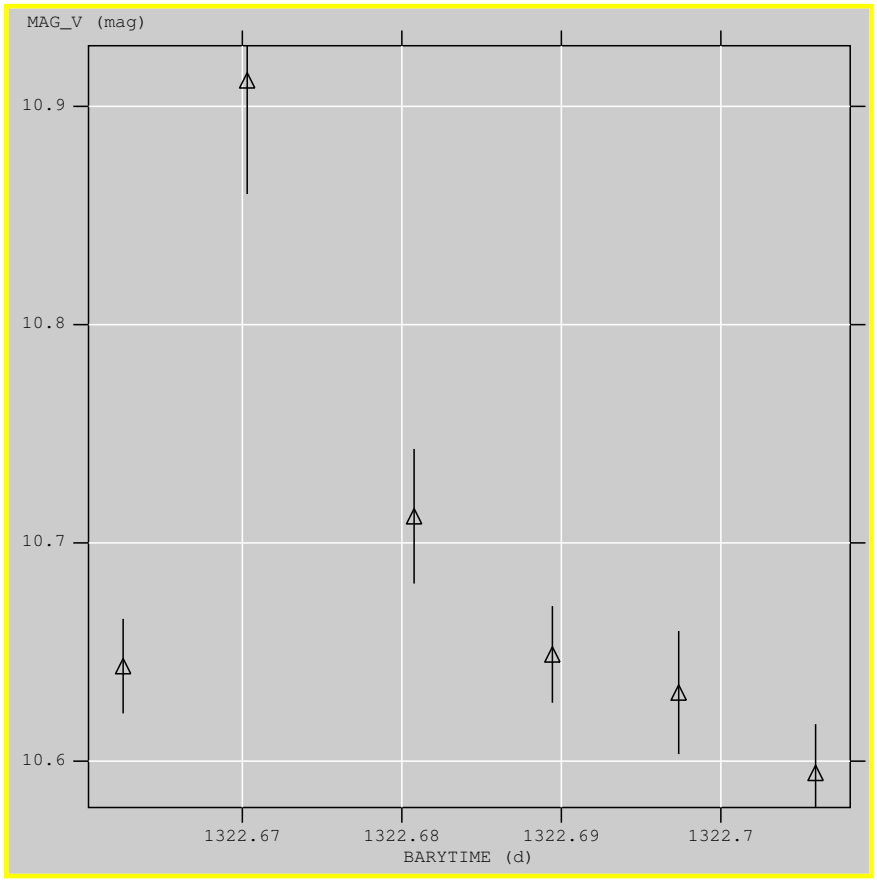

Figure 9: Crab lightcurve.

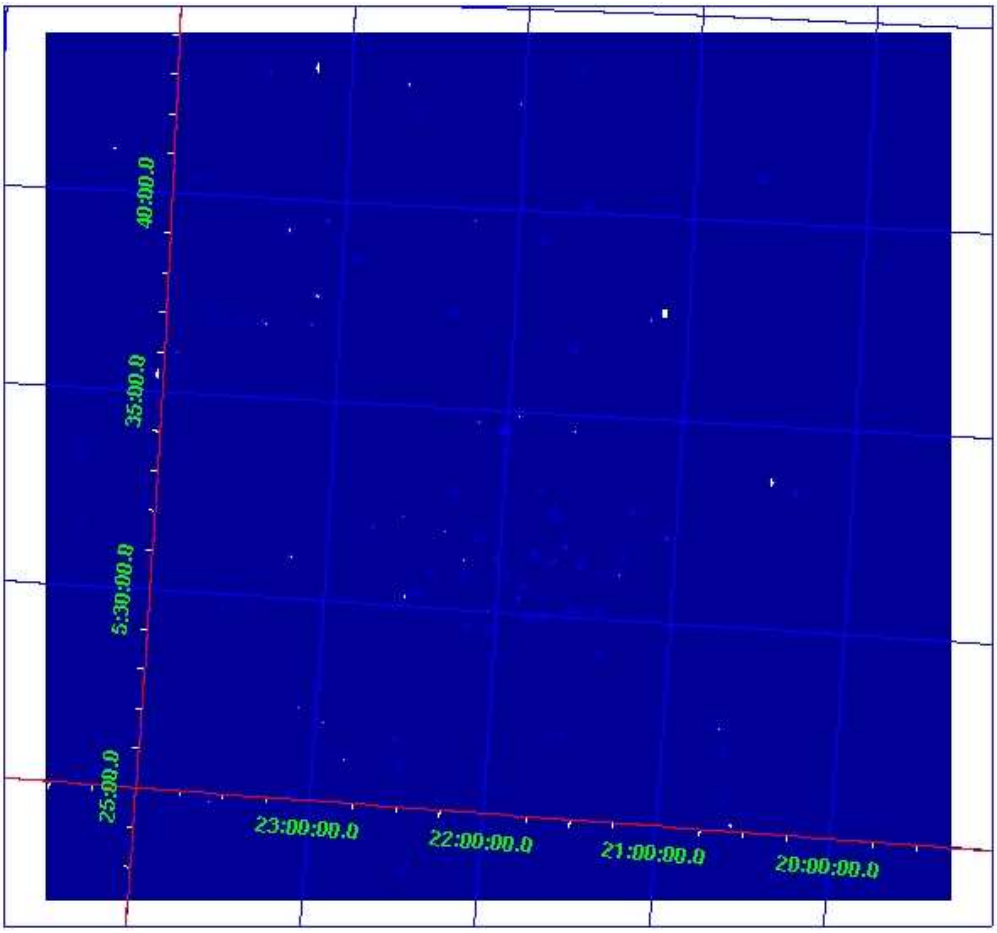

Figure 10: Sky map of the ScW 010200210010, 13^{th} shot.

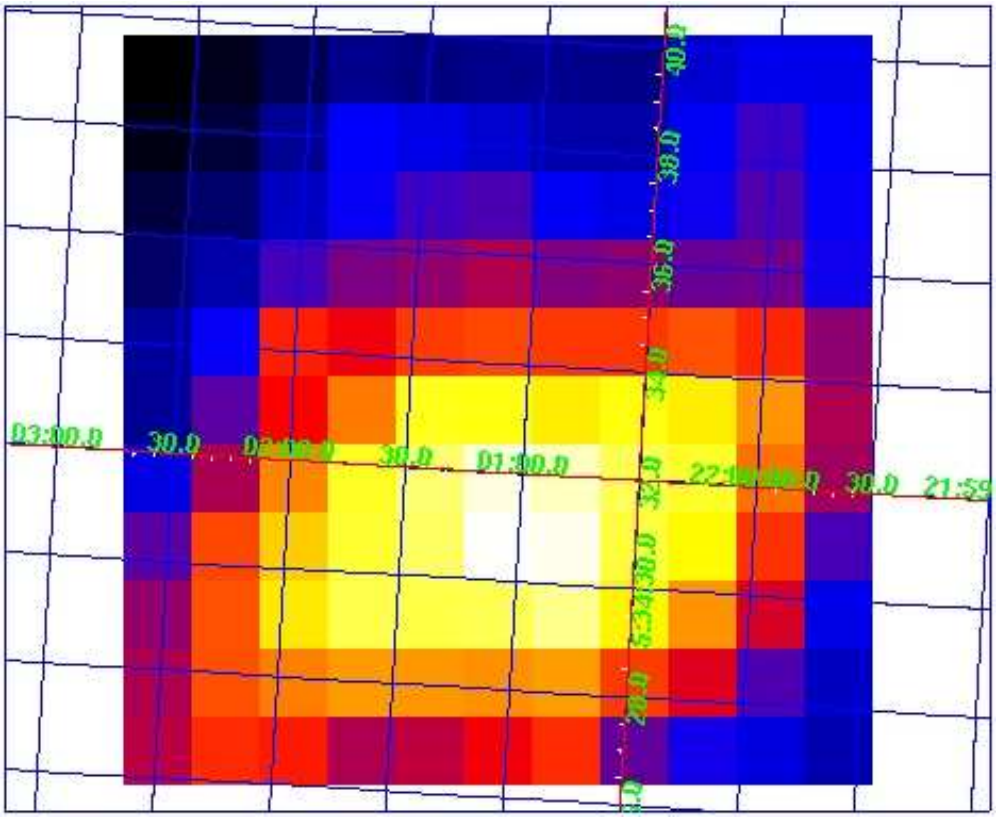

Figure 11: Image of the Crab box, 13$^{\text{th}}$ shot.

8 Basic Data Reduction

In the previous cookbook chapter, the example of the OMC data scientific analysis along with a description of the result was given. In the current chapter, we explain the internal structure of the *omc_science_analysis* script and discuss the intermediate results.

The structure of the main script is illustrated in Fig. 12 along with the input and output Data Structures. In order to avoid having to enter the location of the many Instrument Characteristics files (IC files) by hand, the IC Master Group was created (see more details in [1]).

The *omc_science_analysis* loops over all science windows in the observation group calling for each *omc_scw_analysis* script, performing the actual analysis from the data correction to the source magnitudes calculation. It is possible to run only a subset of the analysis. The full information on the content of the input and output Data Structures is given in the Appendix.

During its work, the *omc_science_analysis* script calls the following low-level scripts:

- *o_cor_science*
- *o_gti*
- *o_src_analysis*

In the following sections, you will also find a more intensive discussion of the parameters included in the main script. Note that the name of the main script parameters differs from the low-level ones by the name of the level added to the low-level script parameter name. You can find information on all the parameters of any low-level script or executable by typing in a command line the name of the executable with `--h` after it, e.g. `o_cor_box_fluxes --h`.

8.1 *o_cor_science*

This script calculates corrected pixel values for the subsequent analysis by removing the background coming from the electronics. The data are converted from analog-digital units (ADU) to electrons, flatfielded, corrected for bias and dark current, with the executable:

- *o_cor_box_fluxes*

This executable performs Bias removal, Dark Current removal, and Flat Fielding.

In determining the bias value to be subtracted, the Dark Current boxes within the data itself are used. Subtracting the Dark Current from the Dark Current boxes leaves a remainder of Bias only. From a user defined 'biastime', a number of Bias array bins within which to determine Bias Values are determined. From biastime, `end_times` are also determined - markers for comparison against `shot_end_times` - for all shots to an `end_time`, use the Bias level determined from the associated bin.

In determining the Bias Level - the mean of all Dark Current pixels (with Dark Current removed) within a bin undetermined, using the Kappa Sigma Clipping algorithm. The number of standard deviations to use as the cutoff, `kscKappa`, is user-defined.

Should data not be available to determine a bias value, the most recently determined bias value is used, and failing that, a previously determined bias value is used.

The corrected output is then ready for photometric flux determination.

All parameters associated with this executable are hidden. IC files and the multiplication factors for data conversion (low and high gain, see Section 3.3 for more details) are provided by the OMC team. Do not change the value of the parameters until you are really sure about what you are doing!

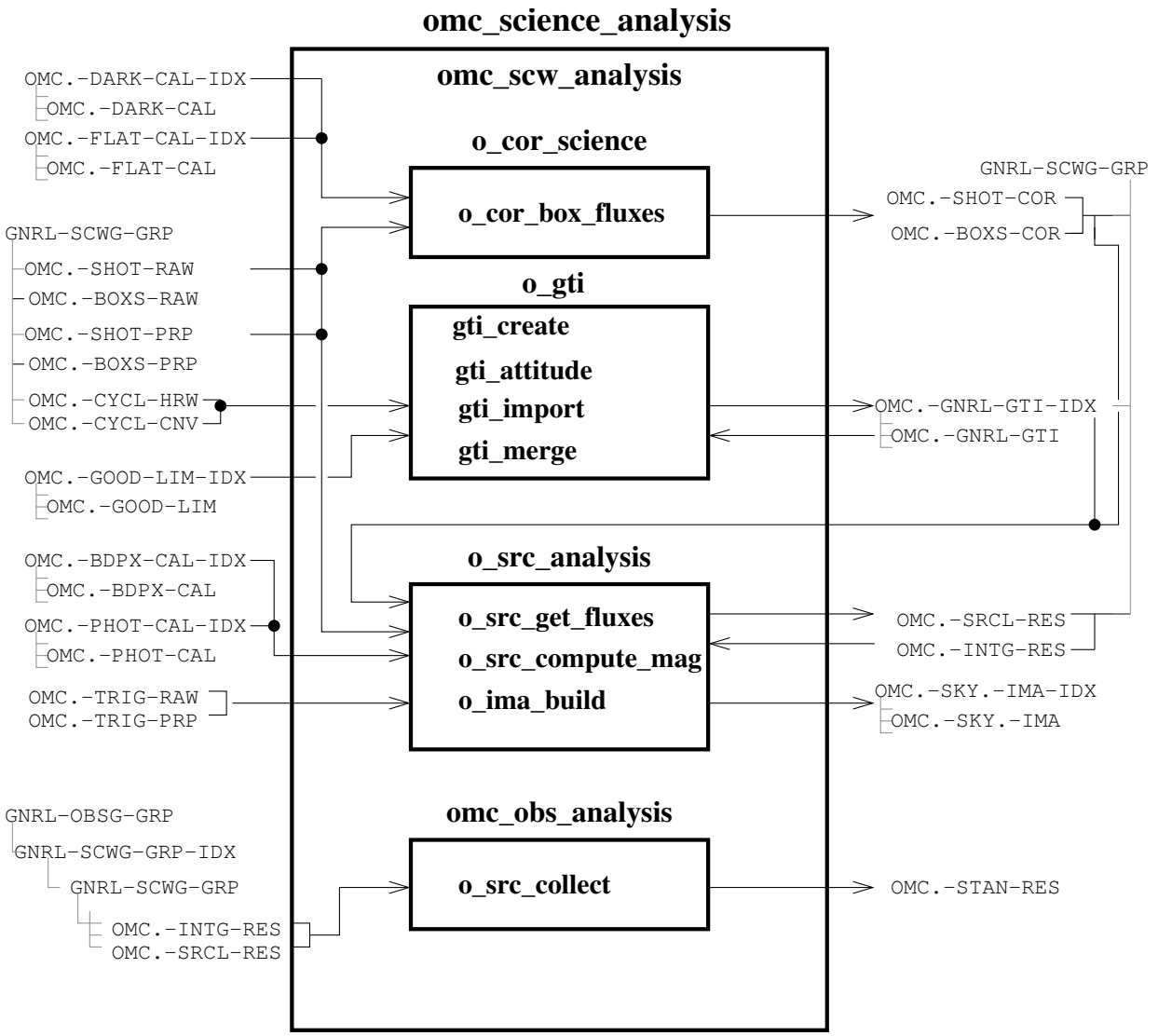

Figure 12: Structure of the *omc_science_analysis* script.

Parameters specific to this level are given in Table 4. The output data structures are described in Section C.1.

Table 4: The *o_cor_box_fluxes* parameters included in the main script.

Name (main script)	Name (executable)	Type	Description
COR_flatField	flatfield	string	DOL of flatfield image (“ ” =take from IC) default: “ ”
COR_darkCurrent	darkpar	string	DOL of dark current & bias calibration table (“ ” =take from IC) default: “ ”
COR_higain	higain	integer	Multiplication factor for high gain default: 5
COR_lowgain	lowgain	integer	Multiplication factor for low gain default: 30

COR_biastime	biastime	integer	Integration time in sec for bias derivation. Possible values `0-100000`. Default: `630`
COR_kscKappa	kscKappa	integer	Number of standard deviations for KSC algorithm. Possible values `1-10`. default: `3`

8.2 *o_gti*

The next part of the Scientific Analysis derives the Good Time Intervals (GTIs) for the current Science Window based on housekeeping data, information about satellite stability and, if given, user defined time intervals. The script *o_gti* calls the following executables to obtain the GTIs:

- *gti_create*
- *gti_attitude*
- *gti_import*
- *gti_merge*

The output data structures are described in Section C.2.

8.2.1 *gti_create*

This program generates all GTIs for one instrument that depend on the housekeeping and other parameters and are defined by comparison of the values with values given in a limit table. It also writes the GTIs in the new GTI tables that are organized in an index group. All GTIs that belong to the same group are merged to one GTI and are written to one GTI Data Structure.

In the course of OMC data analysis, this program is called twice to create GTIs defined by the spacecraft and OMC housekeeping. All parameters associated with this executable are hidden.

Table 5: The *gti_create* parameters included in the main script.

Name (main script)	Name (executable)	Type	Description
GTI_omcLimitTable GTI_scLimitTable	LimitTable	string	The DOL of the GTI limit table. default: " " = take from IC

8.2.2 *gti_attitude*

A spacecraft GTI named "ATTITUDE" is defined for each period of time when the pointing stability is better than the accepted tolerance. For slews, this GTI is always set to be good. All parameters associated with this executable are hidden.

Table 6: The *gti_attitude* parameters included in the main script.

Name (main script)	Name (executable)	Type	Description
GTI_attTolerance	AttStability	real	Defines the accepted attitude stability tolerance in units of arcmin. A GTI is created if the stability is better than this tolerance. default: `0.5`

8.2.3 *gti_import*

The *gti_import* reads user GTI table and converts it to a table in ISDC format. The user GTI can be defined either in units of OBT, IJD, or UTC. The output is always in OBT. The user table can define either bad or good time intervals. The output time intervals are always good ones.

Table 7: The *gti_import* parameters included in the Main script.

Name (main script)	Name (executable)	Type	Description
GTI_gtiUser	InGti	string	DOL of the user GTI table. " "=there is no one. default: " "
GTI_TimeFormat	TimeFormat	string	Time format in which the user GTI is given. possible values: "`IJD`", "`UTC`", "`OBT`" default: "`IJD`"
GTI_Accuracy	Accuracy	string	Accuracy used for OBT to IJD conversion and vice versa. possible values: "`any`", "`inaccurate`", "`accurate`" default: "`any`"

8.2.4 *gti_merge*

This program merges zero, one or more GTIs to a new GTI. It is an AND operation: a time in the result GTI is defined to be "good" if this time is in every input GTI defined as "good".

Table 8: The *gti_merge* parameters included in the Main script.

Name (main script)	Name (executable)	Type	Description
GTI_gtiScNames	SC_Names	string	Names of spacecraft GTIs to be merged. empty=use default default: " "
GTI_gtiOmcNames	OMC_Names	string	Names of OMC GTIs to be merged. empty=use default default: " "
GTI_BTI_Dol	BTI_Dol	string	The DOL of a bad time table (GNRL-INTL-BTI). Default: " "
GTI_BTI_Names	BTI_Names	string	The BTI names of all bad time intervals that should be merged. The names must be separated by one or more blanks or tabs. If a BTI name does not exists in the BTI - table it is assumed to be "good" all the time. Default: " "

8.3 *o_src_analysis*

Extraction of the scientific results from data as well as creation of images is done by the script *o_src_analysis*.

This script derives fluxes and calculates magnitudes for the sources targeted by OMC, calling the following executables:

- *o_src_get_fluxes*
- *o_src_compute_mag*

- *o_ima_build* (optionally)

If the script parameter `IMA_triggerImage` is set to `yes` (default value), then a check for Trigger Mode data will be done and if some are found, *o_ima_build* will be run to create real 81×81, or 91×91 pixel images around the IBIS alert trigger system (IBAS) position for a possible burster.

If the script parameter `IMA_scienceImage` is set to yes, then a file with one image per shot in the Science Window will be created. This file can be large (a few Megabytes per shot and we have a few dozen of shots typically), so the default value is `no`.

One can also restrict the analysis on the IMA step to image creation only, without subsequent analysis, by setting the trigger `IMA_onlyImage` to "yes".

The output data structures are described in Section C.3.

8.3.1 *o_src_get_fluxes*

This executable calculates flux values for all good photometry and science sources in the Science Window Group (SWG). Several shots are combined within a given time interval in order to obtain significant results for weak sources. Photometry shots (SHOTTYPE=1) are co-added in contiguous groups found in the SWG, whereas science shots (SHOTTYPE=2) are co-added to an integration time (in seconds) specified by the "timestep" parameter. The "timestep" is used only as a guide integration time by *o_src_get_fluxes*, which calculates a "real-timestep" to provide a number of co-added shot groups, as close to the input "timestep" as is possible.

Note that while in the photometric shots (SHOTTYPE=1) the targets are only bright photometric sources (TYPE_TAR=1), the target of the science shots (SHOTTYPE=2) can be different: faint photometric stars (TYPE_TAR=1), stars for science analysis (TYPE_TAR=2), and data from the detector shadow are for dark current and bias calibration (TYPE_TAR=3).

In the flux calculation, effects connected to the inconsistency with the planned data and the noise level are taken into account. Bad pixels are determined in the course of calibration analysis and, if possible, are not used in the flux determination. If after all bad pixels were used, then the result would be flagged in the PROBLEMS column (see Table 10 on PROBLEMS flags).

To compute the flux coming from the source, the brightest pixel is searched in a radius of 0-2 pixels (**maxCentOff** parameter) around the box center. This brightest pixel is computed only once for each Science Window Group. It must have a signal-to-noise ratio of at least **IMA_numSigma**, if not, no re-centering is performed.

Taking the above re-centering result as a starting point to compute the source centroid, aperture photometry is performed after combining the data from different shots if it was required by the user according to **IMA_timestep**. The main steps in this algorithm are:

- Estimate the background by using the 11×11 exterior pixel rim. Rejection of high and low pixels is applied to avoid cosmic rays and noisy pixels.
- Use the faint photometric stars to compute the PSF width. To this end, an iterative method has been implemented to minimize the residuals in each pixel according to a Gaussian PSF profile. The fitted values are the centroid (X and Y coordinates) and the PSF width.
- For each source, a small dependence of the PSF width on the X,Y pixel coordinates is corrected by applying a linear relation.
- Compute the centroids of all scientific targets by using an iterative method similar to the one described for computing the PSF. However, in this case, the PSF width is supposed to be known and fixed.
- Calculate the flux using three different apertures: 1×1, 3×3 and 5×5 pixel areas. In 3×3 and 5×5 apertures, partial pixels are used, dividing each real pixel in 4 sub-pixels. The areas are "circularized"

removing the corners in 3×3 and 5×5, giving effective apertures of 8 and 19 square pixels, respectively. The effective apertures are centered on the computed centroids.

- Perform aperture corrections in each one of the computed fluxes (1×1, 3×3 and 5×5).
- Detect source contamination, non point sources, saturated sources or "wrong" sources by analysing the shape of the PSF. These cases are flagged in the PROBLEMS column.

The algorithm used to compute the fluxes takes into account the following effects:

- Dependence of the PSF on lense temperature and satellite attitude, which is difficult to fit by a model.
- Dependence of the PSF on the pixel location over the CCD detector. The relation is linear, so the detector is probably slightly tilted.
- Changes of the sources centroid with time due to OMC thermoelastic deformations as well as the variation of lense temperature.
- Contamination by close sources. The photometric apertures that are used attempt to keep the effect of companions on the derived fluxes as constant as possible.

The World Coordinate System (WCS) support is derived by fitting the best astrometric solution to the faint photometric reference stars. A new solution is computed for each effective integration. This corrects the inaccuracy due to the thermoelastic deformations, which affect the alignment of the OMC optical axes with the spacecraft attitude reference.

Issues deemed to affect the quality of the standard pipeline analysis of individual sources are flagged in the "PROBLEMS" column of OMCSRCLRES and OMCSTANRES. They are stored in an Unsigned Integer Register, any problem encountered is logically AND-ed to the existing register value. Deconstruction of the total into its only possible component values reveal the individual PROBLEMS (see Table 10 for the possible values in the PROBLEMS column).

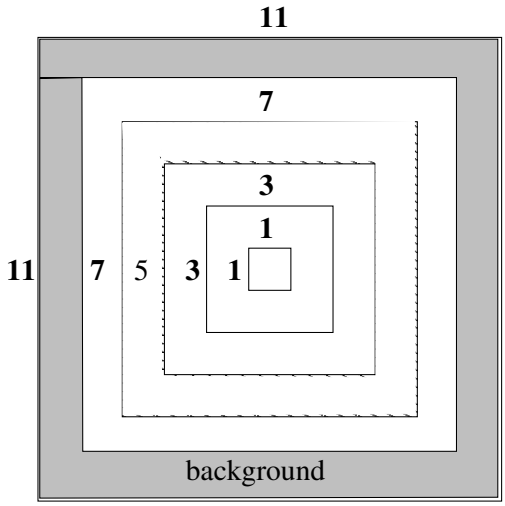

Figure 13: Illustration of the geometry defining the background and source magnitude calculation.

o_src_get_fluxes performs the following quality checks:

- User defines maximum acceptable Standard Deviation on sky background. If this is exceeded, this is flagged in the PROBLEMS column (see Table 10), but the flux calculation continues.

BOX Quality checks:

- entire box within CCD area;
- box is at the planned position;
- box size is as planned;
- box type is the planned type;
- no box pixels are saturated.

Shot Quality Checks:

- shot is the planned type;
- the Shot resides within Good Time Intervals;
- the shot gain is the planned gain;
- the time and number_of_boxes fractions are above the minimum required;
- user can define the minimum shot times. This is useful to select only shots with sufficient exposure for a significant flux detection of a source of interest;
- user can define the maximum shot times. This is useful to avoid shots where the subwindow is saturated for a source of interest.

o_src_get_fluxes determines:

- flux of all objects of interest over 1×1, 3×3 and 5×5 pixel areas centered on the source (Fig. 13);
- the error on the 1×1, 3×3 and 5×5 determined fluxes;
- sky background and its error for each source;
- effective PSF width for each source;
- centering off-sets with respect to the centre of the central pixel. This gives the real position on the CCD in which the photometric apertures have been located to calculate the fluxes;
- derived right ascension and declination (RA_FIN and DEC_FIN) with their error estimates. These coordinates correspond to the computed centroids, i.e., the celestial coordinates in which the photometric apertures have been located to calculate the fluxes. The error estimate corresponds to the accuracy of the WCS support derived for the faint photometric reference stars. For faint scientific sources or for crowded fields, the user should check if the derived coordinates actually correspond to its source.

Table 9: The *o_src_get_fluxes* parameters included in the main script.

Name (main script)	Name (executable)	Type	Description
IMA_timestep	timestep	integer	SHOT grouping bin length in seconds default: `600`
IMA_maxCentOff	maxCentOff	integer	Maximum shift for re-centering integration box possible values: `0`, `1`, `2` default: `2`
IMA_numSigma	numSigma	integer	Minimum standard deviations for peak search in re-centering. possible values: `0` – `10000` default: `2`

IMA_maxshottime	maxshottime	integer	Maximum allowed shot integration time. The rest of the shots will be skipped. default: `200`
IMA_minshottime	minshottime	integer	Minimum allowed shot integration time. The rest of the shots will be skipped. default: `1`
IMA_usePrp	usePrp	boolean	Use prepared data for quality checking default: "`yes`"
IMA_minBoxFrac	minBoxFrac	real	Minimum fraction of planned boxes actually observed possible values: `0.` – `1.` default: `0.99`
IMA_minTimeFrac	minTimeFrac	real	Minimum fraction of planned time actually observed possible values: `0.` – `1.` default: `0.99`
IMA_badPixels	bdpxlpar	string	DOL of Bad Pixel Table (" "=take from IC) default: " "
IMA_noiseLowLeft	noiseLowLeft	real	Read-out noise in e^- for low GAIN, left read-out port (ROP) fault: `45`
IMA_noiseLowRight	noiseLowRight	real	Read-out noise in e^- for low GAIN, right ROP default: `49`
IMA_noiseHighLeft	noiseHighLeft	real	Read-out noise in e^- for high GAIN, left ROP default: `33`
IMA_noiseHighRight	noiseHighRight	real	Read-out noise in e^- for high GAIN, right ROP default: `35`
IMA_skyStdDev	skyStdDev	real	Maximum acceptable Standard Deviation on sky background default: `10.0`

Table 10: Possible values in PROBLEMS column in the *o_src_get_fluxes* output.

Name	Value	Meaning
OMC_PROBLEM_NONE	0	No problems
OMC_PROBLEM_EXTRAPOLATED_MAG	2	The mag was extrapolated
OMC_PROBLEM_BAD_CENTROID	4	No centroid is available or is inaccurate
OMC_PROBLEM_BAD_PSF	8	Bad PSF. A default value was used
OMC_PROBLEM_ANOMALOUS_PSF	16	The PSF shape is anomalous
OMC_PROBLEM_LOW_FLUX_1	32	Flux of central pixel too low
OMC_PROBLEM_BADPIXEL_SKY	128	Bad pixel found in sky bgnd
OMC_PROBLEM_BADPIXEL_RIM_5	256	Bad pixel found in 5x5 rim
OMC_PROBLEM_BADPIXEL_RIM_3	512	Bad pixel found in 3x3 rim
OMC_PROBLEM_BADPIXEL_RIM_1	1024	Central pixel bad
OMC_PROBLEM_SKY_ERROR	4096	Sky error larger than accepted limit
OMC_PROBLEM_UNKNOWN_MAG	8192	Magnitude could not be calculated
OMC_PROBLEM_EXTND_SRC	16384	Source is extended - flux not valid

8.3.2 *o_src_compute_mag*

This executable calculates magnitudes from fluxes for all good sources in the Science Window Group. The executable works on each output table containing the fluxes associated with a single photometric point for every source in the Science Window Group. The executable accomplishes this by extracting the flux for each source in a single table and applying a flux-to-magnitude conversion. Parameter `IMA_magboxsize` defines the area attributed to the source. You can define whether photons from the central point only, or also photons

from 3×3 or 5×5 area are coming from the source. If the real signal-to-noise ratio is less than the value given in the `minSNR` parameter, it is flagged in the PROBLEMS column of OMC.-SRCL-RES (value 8192) and both MAG_V and ERRMAG are set to a value of 99.

The errors analysis considers Poissonian errors, read-out noise, sky background noise and Photometric Calibration noise.

Table 11: The *o_src_compute_mag* parameters included in the main script.

Name (main script)	Name (executable)	Type	Description
IMA_magboxsize	magboxsize	integer	Defines the area attributed to the source when calculating the default magnitude (column MAG_V). However, MAG_V1 MAG_V3 and MAG_V5 are also computed, and they correspond to the magnitude derived by using the 1×1, 3×3 and 5×5 flux areas, respectively. Possible values: `1` = central pixel, `3` = 3×3 area, `5` = 5×5 area default: `3`
IMA_photCal	photCal	string	DOL of photometric calibration curve (" "=take from IC) default: " "
IMA_minSNR	minSNR	real	minimum acceptable signal to noise ratio default: `1.0`

8.3.3 *o_ima_build*

This executable extracts all OMC boxes contained in a Science Window Group. For normal science data and default parameters, a 1072 × 1028 image is built for each shot with the boxes located in their real position on the OMC CCD. The executable can also build "small" images for given sources (see `omc_id` parameter).

If the user chooses to use trigger data, an image is also built for each shot, but the size is that of the trigger window (see `triggersize` parameter).

For some sources, the standard analysis (OSA) is not able to give good results, or simply can not process them. This is the case for extended sources that can even generate a mosaic of OMC boxes, sources with inaccurate coordinates (this happens for most of the high energy targets), or data obtained in trigger mode. For all these cases, the users should execute *o_ima_build* to create standard astronomical images usable by most of the astronomical reduction packages (e.g., IRAF, SEXtractor,...) and visualisation tools (e.g. ds9, ftools,...).

When possible, we recommend that users create corrected images (`level=COR`) for their own processing. In this way, they are sure to use the best calibration data available. This will not be possible for the trigger images, for which "PRP" is the highest level available.

If the requested level is at least PRP, *o_ima_build* will compute and store as an image keyword the barycentric time for the first data element (beginning of the shot). Please note that because the barycentric correction depends on the source position on the sky, the computed barycentric time corresponds to the coordinates of the centre of the OMC FOV.

If the user is only interested in processing one source, he/she can give its OMC_ID and build small images containing only the box corresponding to the selected source. For extended sources or for sources generating several boxes (mosaic), the image will be created containing the mosaic of boxes.

o_ima_build can be launched from *omc_science_analysis* (to process an OG) or *omc_scw_analysis* (to process a SWG). In both cases, *o_ima_build* will store the zero point in magnitudes as an image keyword (`CALZERO`). If the images were created with `level=COR`, then the V magnitude can be calculated as:

$$V = \texttt{CALZERO} - 2.5 * \log(\text{TotalCounts}/\texttt{INT_TIME})$$

where TotalCounts means the total number of counts (e-) for the given source and `INT_TIME` is the integration time. Note that if the level of the images is not "COR", the user must correct for bias, dark current and flatfield before applying the above magnitude relation.

All parameters in *o_ima_build* are also available from *omc_science_analysis* and *omc_scw_analysis*. The user can use both scripts to build the images only (see `IMA_onlyImage, IMA_scienceImage` and `IMA_triggerImage` parameters).

Table 12: The *o_ima_build* parameters.

Name	Type	Description
inswg	string	DOL for input Science Window Group
outfitsname	string	Output name of FITS file, including the .fits extension
datalevel	string	Level of the original data possible values: "`RAW`", "`PRP`", "`COR`"
startshot	integer	Starting shot number to be processed. Note that startshot=`1` means the first shot appearing in the SWG. In general, the first shot will not have SHOT_ID=1. possible values: `1` – `9999` default: `1`
endshot	integer	Ending shot number to be processed possible values: `0` – `9999`, `0` corresponds to the last shot in the Scw. default: `0`

trigger	boolean	Use trigger data to build image? possible values: `y`, `n` default: `n`
triggersize	integer	Size of the trigger window in pixels (only used when `trigger="yes"`). The value of this parameter MUST be the same as used on-board. The images built when trigger data are used will be as large as [triggersize × triggersize]. possible values: `1` – `91` default: `81`
attach	boolean	Attach output data structure to the input SWG? Decides if output index **OMC.-SKY.-IMA-IDX** will be attached to the input SWG. default: `"no"`
clobber	boolean	Clobber existing output data structures? default: `"no"`
chatty	integer	Level of chattiness for the executable possible values: `0` – `3`; (0=very low, 3=very high) default: `1`
mode	string	effective mode of those parameters whose mode is set to "a" (auto)

8.4 *omc_obs_analysis*

This script runs wrap up tasks on a full Observation Group with OMC data. Currently, only the tool *o_src_collect* is called.

8.4.1 *o_src_collect*

This executable combines source data including derived fluxes and magnitudes distributed over several Science Windows into a single table. See Cookbook (Section 7) for an example.

Table 13: The *o_src_collect* parameters.

Name	Type	Description
group	string	DOL of group from which OMC results are read. This can either be an Observation Group or a Science Window Group, though the latter option is rarely useful.
results	string	Name of the output FITS file (including the .fits extension) with combined results.
select	string	CFITSIO selection string applied to input tables. default: `''` (no selection)
attach	boolean	Attach resulting table to group? If set to yes, the newly created table will be attached to the input group. possible values: `y`, `n` default: `n`
chatter	integer	Verbosity of the output. possible values: `0` – `3` default: `1`

9 Known Limitations

1. The automatic extraction of fluxes and magnitudes produce reliable results only for point-like sources.
2. For extended sources or high-energy source counterparts with large uncertainties in their position, the OMC planning assigns multiple adjacent sub-windows to cover the whole area. In that case, multiple boxes are found with different ranks but with the same OMC_ID. These adjacent sub-windows will not be analyzed correctly as the software treats each box individually.

   The photometric extraction has to be done manually in these cases, once the accurate coordinates of the target are known. To help the user, these cases are flagged in the table of results.
3. If the source coordinates are inaccurate by more than 2 OMC pixels (35"), the software analysis will not be able to re-centre the target and the derived fluxes and magnitudes will not be correct.
4. If another star is within a few pixels of the source of interest, it can introduce systematic errors in the derived fluxes and magnitudes. The strength of this effect can be different for different pointings, since the relative position in the sub-windows will slightly change for different rotation angles.
5. Since OSA 4.0, the detection of saturated sources has been improved significantly. However, some of the bright sources slightly saturating one or few pixels might not be detected as saturated sources. As a consequence, their derived magnitudes are not correctly computed. The observer should check whether the source might be saturating the CCD for a given integration time, and reanalyze the data rejecting the shots with the longest integration times.
6. Due to thermoelastic deformations, the alignment of the OMC optical axis with the S/C attitude reference (after correcting the OMC misalignment) may diverge by up to 30" (2 pix). From OSA 5.0 onwards, the derived coordinates are corrected at the time of computing the WCS support by using the photometric reference stars, giving an accuracy better than 2" in most cases.

A Low Level Processing Data Products

A.1 Raw Data

As it was said in the previous part (see sections 4.1, 4.2), during science mode the OMC takes images of the full field of view every 1 to 255 seconds depending on the integration time for the different targets. Each individual OMC CCD integration for image generation is called a "shot". The baseline is to follow a given sequence of different integration times within these limits in order to monitor both bright and faint sources within the FOV: this sequence is configured just before the science mode is entered using a dedicated telecommand. The full image (or a section) is transferred to the data processing electronics. Due to TM constraints, only a number of sub-windows, typically of 11×11 pixels, are extracted around the positions of objects of interest. About 100 such windows are extracted for exposures of 100 s. In the following, the term "box" is used for such a sub-window for clarity. The information from such boxes is transferred to the Earth and added to the **OMC.-SHOT-RAW** and **OMC.-BOXS-RAW** (see Tables 14 and 15).

OMC.-SHOT-RAW is a binary table with information about all shots in the given Science Window (see Table 14). Each row in the table corresponds to one shot. The information concerning the boxes transferred during the given shot and the measured data is located at **OMC.-BOXS-RAW** data structure. Each row in this binary table corresponds to one box.

Table 14: Content of **OMC.-SHOT-RAW** Data Structure.

Column Name	Description
SHOT_NUM	Counter of recorded shots
SHOT_SEQ	Shot sequence number
SHOT_ID	Shot identification
LOBT_ACQ	Local-on-board time of data acquisition
RAW_INTT	Raw integration time as measured on-board
OFFSET_X	Centering offset in X direction
OFFSET_Y	Centering offset in Y direction
ERROFF_X	Centering error in X direction in pixel
ERROFF_Y	Centering error in Y direction in pixel
NUMCSTAR	Number of stars used in the centering error determination
GAIN	Gain setting flag (0=low, 1=high) (see Section 3.3)
READOUT	Read-out port flag (0=left, 1=right)
FIRSTBOX	Position of first box of this shot in OMC.-BOXS-RAW
NUMBOXES	Number of boxes belonging to this shot

Table 15: Content of **OMC.-BOXS-RAW** Data Structure.

Column Name	Description
SHOT_NUM	Counter of recorded shots (used for cross-reference)
SHOT_SEQ	Shot sequence number (used for cross-reference)
SHOT_ID	Shot identification (used for cross-reference)
RANK	The identification number of the box
TYPE_TAR	Type of the target (Science, Photometric ...)
X_TAR	X coordinate of the lower left pixel of the target box
Y_TAR	Y coordinate of the lower left pixel of the target box
SIZE_TAR	Dimension of square box (max. 11 pixels)
PIXELS	Pixel values in ADU

If the trigger mode occurs (see Section 4.4), the raw data are written to the **OMC.-TRIG-RAW** (see Table 16). This data structure is a binary table with one row per shot, as each trigger shot contains only a single box.

Table 16: Content of **OMC.-TRIG-RAW** Data Structure.

Column Name	Description
SSC	Source sequence count of the packets for one shot
PACK_TIME	Time in the data field header of the packets for one shot
NUM_PACKS	Number of packets for this shot
LOBT_ACQ	Local acquisition OBT of the shot
RAW_INTT	Raw integration time of the shot
GAIN	Gain setting flag (0=low, 1=high)
READOUT	Read-out port flag (0=left, 1=right)
OFFSET_X	Centering offset in X direction
OFFSET_Y	Centering offset in Y direction
ERROFF_X	Centering error in X direction in pixel
ERROFF_Y	Centering error in Y direction in pixel
NUMCSTAR	Number of stars used in the centering error determination
X_TAR	X coordinate of the lower left pixel of the target box
Y_TAR	Y coordinate of the lower left pixel of the target box
PIX_FIRST	First pixel contained in the current packet
PIX_LAST	Last pixel contained in the current packet
PIXELS	Pixel values in ADU

A.2 Prepared Data

The ScW Pipeline processes the raw data, converting the local on-board time to the full on-board time and comparing the observed shots and boxes with the planning information sent to the OMC. The planning information is used in the following analyses for the precise information of the source positions. This pipeline also checks the box and pixel fluxes against limits to flag suspiciously high or low values.

The results of the processing of the raw data for the science mode are written to the data structures **OMC.-SHOT-PRP** and **OMC.-BOXS-PRP** (see Tables 17 and 18). These data structures have a structure similar to the one for the RAW data.

Table 17: Content of **OMC.-SHOT-PRP** Data Structure.

Column Name	Description
OBT_ACQ	On-board time of data acquisition
INT_TIME	Effective integration time
BOX_PLAN	The number of boxes planned for this shot
BOX_FRAC	The fraction of observed boxes vs. planned
TIMEFRAC	Fraction of observed/planned integration time
PLAN_OK	Has this shot planning data? (0=no, 1=yes)
TYPE_OK	Shot type agrees with planning? (0=no, 1=yes)
GAIN_OK	Target gain agrees with planning? (0=no, 1=yes)
SHOTTYPE	Shot type (1=photometry, 2=science)
FIRSTBOX	Position of first box of this shot in OMC.-BOXS-PRP
NUMBOXES	Number of boxes belonging to this shot

Table 18: Content of **OMC.-BOXS-PRP** Data Structure.

Column Name	Description
MEANFLUX	Mean flux of box in ADU
STDDEV	Standard deviation of flux distribution within box
FLUXLEVL	Flag to denote if box is normal, saturated or blank (0,1,-1)
POS_OFF	Flag if box position is inconsistent with planning
SIZE_BAD	Flag if box size is inconsistent with planning
TYPE_BAD	Flag if box target type is inconsistent with planning

RANK_BAD	Flag if no planning data can be found for this rank number
FAINTPHO	Flag to mark “faint photometric” sources in science data
OMC_ID	OMC catalogue source identifier
RA_OBJ	Source right ascension in degrees
DEC_OBJ	Source declination in degrees
EXTENSION	Source extension
MAG_V	Source visual (Johnson’s) magnitude
SIGMA_V	Source variability

The prepared raw data for the trigger mode are kept in the **OMC.-TRIG-PRP**, see Table 19.

Table 19: Content of **OMC.-TRIG-PRP** Data Structure.

Column Name	Description
OBT_ACQ	Full on-board time of the shots
INT_TIME	Effective integration time of the shots

B Instrument Characteristics Data used in Science Analysis

About once every two months, dark current calibration and flat field calibration modes are foreseen. The off-line dark current analysis derives the dark current, slope, offset and bias values, keeping it at **OMC.-DARK-CAL** (see Table 20).

Table 20: Content of **OMC.-DARK-CAL** Data Structure.

Column Name	Description
OB_TIME	On-board acquisition time
INT_TIME	Integration time of dark current shot
DARK_CURRENT	Mean dark current in electrons/pixel
VARIANCE	Variance of dark current
GAIN	Gain setting flag (0=low, 1=high)
READOUT	Read-out port flag (0=left, 1=right)
Y_BIN	Y binning setting

The off-line full-field analysis calculates normalized flatfield data and keeps it at **OMC.-FLAT-CAL**. The normalized flatfield data are stored straightforwardly as an image with the information about the dimensionless flatfield values (with mean value of order 1.0) and axes along the X and Y CCD axes.

The **OMC.-BDPX-CAL** contains the look up table of bad OMC pixels (see Table 21).

Table 21: Content of **OMC.-BDPX-CAL** Data Structure.

Column Name	Description
DETX	X-coordinate of bad pixel position
DETY	Y-coordinate of bad pixel position
BADFLAG	Integer flag defining the nature of the bad pixel (1=cold pixels 2=hot pixels)

The results of the **photometric calibration** of the OMC are in the **OMC.-PHOT-CAL** data structure (Table 22). It is a binary table which contains the information about the measured flux in electron/sec, the corresponding photometric magnitude and the estimation of its error.

Table 22: Content of **OMC.-PHOT-CAL** Data Structure.

Column Name	Description
LOGFLUX	Measured flux in electron/sec
MAG_V	Corresponding photometric magnitude
ERRMAG_V	Error estimate for V magnitude

The parameter limits defining good time intervals for the OMC instrument are kept in the **OMC.-GOOD-LIM**.

Table 23: Content of **OMC.-GOOD-LIM** Data Structure.

Column Name	Description
PAR_NAME	Parameter name
OBT_START	Start of validity of the limit values
OBT_END	End of validity of the limit values
MIN_VAL	Minimum values allowed (4 values of increasing importance)
MAX_VAL	Maximum values allowed (4 values of increasing importance)
GTI_NAME	Name of the group to which the parameter belongs
SUB_ASSEMBLY	Identifier of the instrument sub-assembly
CHECK_MODE	Modes in which the parameters must be checked

C Science Data Products

C.1 *o_cor_science*

At this step, pixel values are corrected for the background coming from the electronics.

The resulting corrected data are written to the **OMC.-BOXS-COR** and **OMC.-SHOT-COR** data structures. **OMC.-BOXS-COR** contains the corrected pixel values in electrons for all boxes of a given shot. Each row of this binary table contains data for one box. Data in **OMC.-SHOT-COR** tells you which boxes in **OMC.-BOXS-COR** correspond to a given shot (Table 24).

Table 24: Content of **OMC.-SHOT-COR** Data Structure.

Column Name	Description
FIRSTBOX	Position of first box of this shot in OMC.-BOXS-COR
NUMBOXES	Number of boxes belonging to this shot
BIAS_LEVEL	Bias level value for this shot
BIAS_STDDEV	Bias level standard deviation

C.2 *o_gti*

This script derives good time intervals based on housekeeping data, information about satellite stability and data gaps.

The results are written to the data structure **OMC.-GNRL-GTI** containing the good time intervals for the OMC and to the **OMC.-GNRL-GTI-IDX** (the index of all **OMC.-GNRL-GTI** data structures).

Table 25: Content of **OMC.-GNRL-GTI** Data Structure.

Column Name	Description
OBT_START	On-board time of start of the GTI
OBT_END	On-board time of end of the GTI

C.3 *o_src_analysis*

This script derives fluxes, calculates magnitudes and produces images for the sources targeted by the OMC.

The results of the script are kept in the **OMC.-SRCL-RES** (see Table 26) and **OMC.-INTG-RES** (see Table 27). **OMC.-SRCL-RES** is a binary table with each row corresponding to one target box (several shots are combined within a given time interval in order to obtain significant results for weak sources). Photometry shots (SHOTTYPE=1) are co-added in contiguous groups found in the SWG, whereas science shots (SHOTTYPE=2) are co-added to an integration time (in seconds) specified by the "timestep" parameter.

Note that while in the photometric shots (SHOTTYPE=1) the targets are only photometric bright sources (TYPE_TAR=1), the target of the science shots (SHOTTYPE=2) can be different; faint photometric stars (TYPE_TAR=1), stars for science analysis (TYPE_TAR=2), and data from the detector shadowed are for dark current and bias calibration (TYPE_TAR=3). **OMC.-INTG-RES** is a binary table where each row corresponds to one integration within a given Science Window.

Table 26: Content of **OMC.-SRCL-RES** Data Structure.

Column Name	Description
INTG_NUM	Counter of recorded integrations (used for cross-reference)
OMC_ID	OMC catalog source identifier

TYPE_TAR	Target type (Photometric (1), Science (2), ...)
RA_OBJ	Source right ascension in degrees
DEC_OBJ	Source declination in degrees
RA_FIN	Derived right ascension in degrees
DEC_FIN	Derived declination in degrees
RA_FIN_ERR	Standard error for RA_FIN*cos(DEC_FIN)
DEC_FIN_ERR	Standard error for DEC_FIN
EXPOSURE	Effective exposure time in seconds
FLUX_1	Flux in electron/s derived from 1×1 integration boxes
ERFLUX_1	Error estimate for FLUX_1
FLUX_3	Flux in electron/s derived from 3×3 integration boxes
ERFLUX_3	Error estimate for FLUX_3
FLUX_5	Flux in electron/s derived from 5×5 integration boxes
ERFLUX_5	Error estimate for FLUX_5
SKYBACK	Mean flux from sky background in electron/pixel/s
SKYERROR	Error estimate for SKYBACK
MAG_V1	Computed V magnitude for the 1x1 pixel area
ERRMAG_V1	Error estimate for V magnitude in 1x1 pixel area
MAG_V3	Computed V magnitude for the 3x3 pixel area
ERRMAG_V1	Error estimate for V magnitude in 3x3 pixel area
MAG_V5	Computed V magnitude for the 5x5 pixel area
ERRMAG_V1	Error estimate for V magnitude in 5x5 pixel area
CATMAG_V	Catalog V (Johnson) magnitude
CATERR_V	Catalog error estimate for V magnitude
PROBLEMS	Flag for various problems
FLAG	Generic flag
CENTRING_X	Derived X-axis offset of the source from the box center
CENTRING_Y	Derived Y-axis offset of the source from the box center
X_TAR	X coordinate of the lower left pixel of the target box
Y_TAR	Y coordinate of the lower left pixel of the target box
RANK	Unique rank number of the box for the current pointing
PSF_FWHM	Effective PSF FWHM in pixels

Table 27: Content of **OMC.-INTG-RES** Data Structure.

Column Name	Description
INTG_NUM	Counter of recorded integrations (used for cross-reference)
OBTFIRST	On-board time of the first data element
OBTLAST	On-board time of the last data element
TFIRST	Time of the first data element, IJD
TLAST	Time of the last data element, IJD
TELAPSE	Total elapsed time of the data
SHOTTYPE	Shots type (1:photometry, 2:science)
SHOTFRST	Shot identification of first shot
SEQFRST	Shot sequence number of first shot
SHOTLAST	Shot identification of last shot
SEQLAST	Shot sequence number of last shot
FIRSTSRC	Position of first source of this integration in OMC.-SRCL-RES
NUMSRCES	Number of sources belonging to this integration

C.3.1 *o_ima_build*

This executable extracts all OMC boxes contained in a Science Window Group. For normal science data, a 1072 × 1028 image is built (data structure **OMC.-SKY.-IMA**) for each shot with the boxes located in their real position on the OMC CCD. If the user chooses to use trigger data, an image is also built for each

shot, but the size is that of the trigger window. The index file is written to the **OMC.-SKY.-IMA-IDX** data structure (see Table 28).

Table 28: Content of **OMC.–SKY.-IMA-IDX** Data Structure.

Column Name	Description
SHOT_SEQ	Shot sequence number
SHOT_ID	Shot ID
DATAMODE	Instrument data mode
SHOTTYPE	Shot type (1:photometry, 2:science, -1: undefined)
X_WINORG	X coordinate of the image from left ROP
Y_WINORG	Y coordinate of the image from left ROP
LOBT_ACQ	Local-OBT acquisition time
OBT_ACQ	On-board time of data acquisition
RAW_INTT	Raw integration time
INT_TIME	Integration time
OFFSET_X	Centering offset in X direction
OFFSET_Y	Centering offset in Y direction
ERROFF_X	Centering error in X direction
ERROFF_Y	Centering error in Y direction
NUMCSTAR	Number of stars used in the centring error determination
NUMBOXES	Number of boxes belonging to this shot
GAIN	Gain setting flag (0=low, 1=high)
READOUT	Read-out port flag (0=left, 1=right)
DATALEVL	Processing level of data used to build image
SIGWCS_X	1-sigma X-axis accuracy of WCS solution
SIGWCS_Y	1-sigma Y-axis accuracy of WCS solution
OMC_ID	OMC catalogue source identifier
TFIRST	Time of the first data element
BARYTIME	Barycentric time for the first data element
X_WINSIZ	X size of the box
Y_WINSIZ	Y size of the box

C.4 *o_src_collect*

This executable combines source data, including derived fluxes and magnitudes distributed over several Science Windows into a single table **OMC.-STAN-RES** (see Table 29).

Table 29: Content of **OMC.-STAN-RES** Data Structure.

Column Name	Description
REVOL	Revolution number valid for time of data taking
SWID	Science Window identifier from which this row was taken
TFIRST	Time of the first data element
BARYTIME	Barycentric time for the first data element
TELAPSE	Elapsed time of the integration in seconds
EXPOSURE	Effective integration time in seconds
SHOTTYPE	Type of shots used for building integration
OMC_ID	OMC catalog source identifier
TYPE_TAR	Target type (Science, Photometric, ...)
RA_OBJ	Source right ascension in degrees
DEC_OBJ	Source declination in degrees
FLUX_1	Flux in electron/s derived from 1×1 integration boxes
ERFLUX_1	Error estimate for FLUX_1
FLUX_3	Flux in electron/s derived from 3×3 integration boxes
ERFLUX_3	Error estimate for FLUX_3

FLUX_5	Flux in electron/s derived from 5×5 integration boxes
ERFLUX_5	Error estimate for FLUX_5
SKYBACK	Mean flux from sky background in electron/pixel/s
SKYERROR	Error estimate for SKYBACK
SIZE_MAG	Integration box size for deriving MAG_V
MAG_V	Computed V (Johnson) magnitude
ERRMAG_V	Error estimate for V magnitude
CATMAG_V	Catalog V (Johnson) magnitude
CATERR_V	Catalog error estimate for V magnitude
MAG_V1	Computed V magnitude for the 1×1 pixel area
ERMAG_V1	Error estimate for V magnitude in 1×1 pixel area
MAG_V3	Computed V magnitude for the 3×3 pixel area
ERMAG_V3	Error estimate for V magnitude in 3×3 pixel area
MAG_V5	Computed V magnitude for the 5×5 pixel area
ERMAG_V5	Error estimate for V magnitude in 5×5 pixel area
PROBLEMS	Flag for various problems
NOISE_LL	Read-out noise in e- (low gain, left ROP)
NOISE_LR	Read-out noise in e- (low gain, right ROP)
NOISE_HL	Read-out noise in e- (high gain, left ROP)
NOISE_HR	Read-out noise in e- (high gain, right ROP)
CENTRING_X	Derived X-axis offset of the source from the box centre
CENTRING_Y	Derived Y-axis offset of the source from the box centre
PSF_FWHM	Effective PSF FWHM in pixels
X_TAR	X coordinate of the lower left pixel of the target box
Y_TAR	Y coordinate of the lower left pixel of the target box
RANK	Rank = (CUR_TABLE-1)*57+TAR_RANK
RA_FIN	Derived right ascension in degrees
RA_FIN_ERR	Standard error for RA_FIN*cos(DEC_FIN)
DEC_FIN	Derived declination in degrees
DEC_FIN_ERR	Standard error for DEC_FIN

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